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ABSTRACT

These hearings focused on the major problems and opportunities in marine research and on the role of both the government and the scientific community in responding to future needs. Included are statements by: James Baker; Donald Boesch; Robert Corell; Tudor Davies; M. Grant Gross; G. Ross Heath; Joel Pritchard; David Ross; J. R. Schubel; Gerry Studds; the United States Geological Survey; Ferris Webster; Robert Winokur; Paul Wolff; and Larry Wortzel. Also included (when applicable) is supporting documentation provided by these individuals as well as communications submitted for the record. This documentation includes: information on ocean and marine resources and research priorities and initiatives; information on significant challenges in ocean science through the next decade; a brief history (1964-present) of the ALVIN program and the navy-owned deep submersible research vessel (DSRV-ALVIN); an article by Robert Wall entitled "The Oceanography Report--Ocean Sciences Peer Review in the NSF" (National Science Foundation); articles by David Ross and John Knauss entitled "How the Law of the Sea Will Affect U.S. Marine Science" and by David Ross and Michael Healey entitled "International Marine Science: An Opportunity for the Future"; a discussion of estuarine research priorities; and answers to various questions considered during the hearings. (JN)

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STATUS OF U.S. MARINE RESEARCH

HEARING

BEFORE THE

SUBCOMMITTEE ON OCEANOGRAPHY

OF THE

COMMITTEE ON MERCHANT MARINE AND FISHERIES
HOUSE OF REPRESENTATIVES

NINETY-EIGHTH CONGRESS

SECOND SESSION

ON

U.S. MARINE SCIENTIFIC RESEARCH CAPABILITIES OVERSIGHT

SEPTEMBER 26, 1984

Serial No. 98–54

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STATUS OF U.S. MARINE RESEARCH

WEDNESDAY, SEPTEMBER 26, 1984

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON OCEANOGRAPHY,
COMMITTEE ON MERCHANT MARINE AND FISHERIES,
Washington, DC.

The subcommittee met, pursuant to notice, at 1:35 p.m., in room 1334, Longworth House Office Building, Hon. Gerry E. Studds, presiding.

Present: Representatives Studds, Tauzin, Pritchard, and Schneider.

Staff present: Bill Woodward, Darrell Brown, Mary Pat Barrett, Katherine Minsch, Becky Roots, Curt Marshall, Candyce Clark, and Patience Whitten.

OPENING STATEMENT OF HON. GERRY E. STUDDS, A U.S. REPRESENTATIVE FROM THE STATE OF MASSACHUSETTS

Mr. STUDDS. The subcommittee will come to order.

In the absence of Chairman D'Amours, about whose whereabouts we shall not speculate, and at his request, I will be chairing this meeting.

The Subcommittee on Oceanography meets today to conduct an oversight hearing on marine scientific research, the first such hearing held by the subcommittee since 1978. Our goal this afternoon is to identify in summary form the major problems and the major opportunities in this field, and to discuss the role of both the Government and the scientific community in responding to future needs.

The general questions we have are simple: What do we most need to learn about the oceans during the years ahead?

How will the equipment and the funding be obtained to carry out the needed research?

How can we guarantee that the data obtained will be used in a coordinated and efficient way?

I am certain that no one in this room doubts the value of marine scientific research; nor, I am sure, do they doubt the potential of the Government to diminish that value through bureaucratic duplication, budgetary confusion, and a lack of coordination among the agencies and departments sharing responsibility in this field. Both scientists and the Government will be well represented during this hearing today, and I trust that the guidance we obtain from each of our two panels will erase any lingering doubts about whether or not we are placing the proper emphasis on scientific research in the oceans, and about whether or not our resources are being properly used.

We have a lot of witnesses today, a lot of ground to cover, and not a great deal of time. I hope that all the participants will be as specific as they can be in their recommendations and that we will make the best possible use of the time we have available this afternoon.

Our first panel, if it can proceed in its entirety up here is: Dr. James Baker, president of the Joint Oceanographic Institutions, Inc.; Dr. Donald Boesch, director of Louisiana Universities Marine Consortium; Dr. Robert Corell, director, University of New Hampshire/University of Maine Joint Sea Grant Program; Dr. Ross Heath, dean of the College of Ocean and Fisheries Science, University of Washington; Dr. David Ross, director of the marine policy and ocean management program, Woods Hole; and Dr. J.R. Schubel, director of marine sciences research center of the State University of New York. There should be six of you, according to this.

Gentleman, I understand that you have been advised, forewarned, and importuned, among other things, by the staff to restrict your oral testimony to no more than 5 minutes, and I have been instructed by Chairman D'Amours, who is as good a person as any to blame for this, to cut you off promptly at the end of 5 minutes, with the possible exception, of course, of Woods Hole, which is accorded 5¼ minutes.

Your written statements will appear in their entirety in the record. We will go in the order in which I read the names of the six of you. At the conclusion of each of your six no longer than 5 minute oral presentations, we will go to questions from the subcommittee.

We thank you for being here, we welcome you, and, first, Dr. Baker.

STATEMENT OF DR. JAMES BAKER, PRESIDENT, JOINT OCEANOGRAPHIC INSTITUTIONS, INC., WASHINGTON, DC

Dr. BAKER. Thank you, Mr. Chairman.

I am James Baker, president of Joint Oceanographic Institutions, a nonprofit corporation that coordinates and manages large research programs for the 10 largest academic oceanographic institutions that operate seagoing research vessels. At present, I am also Acting Chairman of the National Academy of Sciences' Board on Ocean Science and Policy and Chairman of the Board's Committee on Ocean Climate Research.

Joint Oceanographic Institutions currently manages the ocean drilling program, a $30 million per year program of scientific ocean drilling that involves 10 U.S. institutions and an equal number of non-U.S. institutions, all of whom contribute to the funding. The central purpose of ocean drilling is to provide core samples and information from the world's oceans needed to improve our understanding of the origin and development of the ocean basins. Because the ocean is the last frontier for mineral and petroleum resources, the importance of a thorough understanding of its geologic history and framework cannot be overstated.

In recognition of the fact that oceanography is ready to launch a bold new program to understand the ocean using data collected from satellites, our Board of Governors has also appointed a satellite planning committee. The committee has noted that a century of measurements from ships and buoys has not only expanded our knowledge of the oceans, but also revealed the limits of these traditional techniques. A decade of measurements from satellites, launched largely for other purposes, has now shown that a new and more sweeping view of ocean phenomena can be obtained from space.

From deep sea drilling to ocean satellites, oceanographers are looking forward to major new advances in understanding and prediction of ocean processes. But in order to address the new challenges, the basic infrastructure of oceanography must be strengthened in the immediate future.

Today in the United States, the ocean sciences share two characteristics with other field and laboratory sciences: preeminence in world science and a deteriorating infrastructure. But the former, the preeminence, is being challenged by the latter. On the whole, our laboratory equipment is old, we are not up to date with computers, our research fleet will need replacement in a few years, and shipboard equipment and handling gear are not adequate for the major new programs that are planned. Our suite of available equipment suffers in comparison with that used by industry, for example, in mineral exploration, and by other countries, in particular, Great Britain, France, West Germany, and Japan.

Of all the field sciences, oceanography faces perhaps the most severe environmental and economic constraints. Relative to most other environments, the salty and turbulent ocean is harsh and corrosive. As a consequence, instruments have short lifetimes. On the economic side, one cause of our deteriorating infrastructure can be traced to the rapid escalation of fuel costs for research vessels in the late 1970's. At that time, funding was diverted to day-to-day operating costs.

In considering the support of ocean sciences, our Board of Governors has looked broadly at the needs of the field. We have identified immediate needs in equipment support for laboratories, ships, other platforms, support personnel, data management systems, and educational facilities.

Much of the future work of oceanography will be done from unmanned platforms, ranging from drifting buoys to satellites. These platforms support a suite of instrumentation that must be continually upgraded to become more efficient and more precise. New high technology sensors and low power electronics will have an important impact here.

Important to infrastructure also is the concept of regional and national facilities. In general, our oceangoing research vessels operate as regional facilities, scheduled and used by a broad community of marine scientists. At sea, we find ourselves in the midst of a data explosion as we use more high data rate instrumentation. We find that our infrastructure is poorly designed to handle both the quantities of data and the maintenance and operation of the new instrumentation. In order to make proper use of these new capabilities, we need both highly qualified technical support and comprehensive data management systems at the major research laboratories.

Also, we find that exciting research opportunities require such an investment in specialized equipment and support that the field can only provide one, or, at most, very few of these research facilities. Hence, we believe that oceanographers are coming to accept the concept of national facilities.

In summary, we see a tremendous potential for addressing primary scientific questions with new technology. The challenge of the oceans has become an opportunity for breakthroughs in understanding and prediction of our environment. It is thus crucial that the basic infrastructure of the field be strengthened and supported. The Board of Governors of Joint Oceanographic Institutions has long been aware of this need, and would be happy to work with the subcommittee on ways to address the issues.

[Statement of Dr. Baker follows:]

STATEMENT OF DR. D. JAMES BAKER, PRESIDENT, JOINT OCEANOGRAPHIC INSTITUTIONS INC.

Mr. Chairman, I am D. James Baker, President of Joint Oceanographic Institutions, a non-profit corporation that coordinates and manages large research programs for the ten largest academic oceanographic institutions that operate sea-going research vessels. At present, I am also Acting Chairman of the National Academy of Sciences' Board on Ocean Science and Policy and Chairman of the Committee on Ocean Climate Research. I am also a member of the NASA Space and Earth Sciences Advisory Committee and the Panel on Environmental Support of the Naval Research Advisory Committee. My Scientific expertise is in physical oceanography and air-sea interaction.

Joint Oceanographic Institutions currently manages the Ocean Drilling Program, a $30 million per year program of scientific ocean drilling that involves ten U.S. institutions and an equal number of non-U.S. institutions, all of whom contribute to the funding. The central purpose of ocean drilling is to provide core samples and information from the world's oceans needed to improve our understanding of the origin and development of the ocean basins. Because the ocean is the last frontier for mineral and petroleum resources, the importance of a thorough understanding of its geologic history and framework cannot be overstated.

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In summary, we see a tremendous potential for addressing primary scientific questions with the new technology. The challenge of the oceans has become an opportunity for breakthroughs in understanding and prediction of our environment. It is thus crucial that the basic infrastructure of the field be strengthened and supported. The Board of Governors of Joint Oceanographic Institutions has long been aware of this need, and would be happy to work with the subcommittee on ways to address the issues.

[EDITOR'S NOTE.—The following document was submitted along with Dr. Baker's testimony and has been retained in subcommittee files: "Oceanography from Space: A Research Strategy for the Decade 1985-1995—An Executive Summary," by the Satellite Planning Committee of Joint Oceanographic Institutions, Inc., 1984.]

Mr. STUDDS. Thank you, Dr. Baker. With scientific precision, you were 5 minutes.

The Pavlovian bells you just heard indicate that, like the rest of the subcommittee, I must disappear across the street for just a moment. There is a vote on the House floor, and we will suspend for roughly 10 minutes. We will resume at that point with Dr. Boesch.

[Short recess taken.]

Mr. PRITCHARD [acting chairman]. We are going to get started. Our chairman is with the Speaker for a moment. He will be here, hopefully, in a few minutes, but we may have other interruptions. So, let's get started.

We will now ask Dr. Donald Boesch, director of Louisiana Universities Marine Consortium, for his statement. Dr. Boesch?

STATEMENT OF DR. DONALD BOESCH, DIRECTOR, LOUISIANA UNIVERSITIES MARINE CONSORTIUM, CHAUVIN, LA

Dr. BOESCH. Thank you.

I am Donald Boesch. I am director of Louisiana Universities Marine Consortium, an organization of the State's 13 public universities for marine research and education.

I would like to speak today specifically on my experience in research on marine environmental quality. That experience is based upon working with a variety of Federal agencies—NOAA, EPA, Interior, the Corps of Engineers, and the National Science Foundation. Particularly, I would like to address the prospects and limitations of applied marine research and availability and coordination of the Federal oceanographic assets in research on marine environmental quality.

Although some of my comments will be critical, I want to, at the start, express my enthusiasm and optimism for the next few decades. As Dr. Baker indicated, we have a lot of bright, promising things on the horizon in oceanography, and we would like to see some of those developments, of course, applied to our practical problems as well.

There are, of course, numerous Federal, State, and local agencies which have interests and responsibilities concerning marine environmental quality and, thus, sponsor research on the subject. Within the Federal Government, there are at least seven departments and three independent agencies which do so, at least partially.

In addition to this bureaucratic complexity that the research scientist faces, there is, of course, the notorious environmental complexity which must be unraveled. Environmental scientists are asked to sort out impacts within environments which are poorly understood and highly dynamic. More than any other field in marine research that I know, research on marine environmental quality is subject to frequent changing, blustery winds of public concerns, political pressures, and legal mandates which often direct or limit research to proximate rather than ultimate issues.

There are several aspects that I would like to address in looking toward the future. The first is the need for innovation in improving the quality of marine environmental quality research.

There is a general viewpoint held in the oceanographic community that much of this research is regarded as of inferior quality and, also, is not very well coupled with our advances in basic research. So, in general, applied environmental research is not effectively assimilating the products of basic oceanographic research nor effectively utilizing state-of-the-art approaches developed in basic research. This translation of basic science findings to our practical understanding of how we influence the ocean is obviously an area that needs to be enhanced and improved.

Another stultifying aspect of this results from the policies which govern the selection of performers of research which sometimes have an effect of limiting innovation in applied environmental research. The procurement process can limit the input of nongovernmental scientists in the very design of the research and also discourage academic scientists from involvement because of narrowly defined scopes of work, rapid responses required, and onerous requirements for proposal boilerplate.

There are avenues, obviously, for academic scientists to have an input. I have been involved in several of those through the National Research Council and as chairman of the Department of the Interior's Scientific Committee of the OCS Science Policy Board. These are, I think, exercises which have a lot of promise, but sometimes the actual effectiveness seems to lack in terms of actually experiencing implementation of recommendations.

There are some important challenges in research and monitoring that we face in the future over the next 10 to 20 years. How can these needed advances be achieved? How can we efficiently and meaningfully assure that the marine environment is sufficiently healthy? Indeed, what constitutes environmental health? These are substantial questions which must guide our approaches.

In particular, I think we need to look carefully at what environments we should be concerned about. Historically, most of the early pollution research was based on estuarine and coastal waters. We had a shift in the period of the late 1970's and early part of this decade to research on continental shelves with respect to ocean dumping, oil and gas development, and the like. Now, we see a return of agency interest to coastal environments.

We need improved understanding of biological systems, coupling what we are able to determine experimentally with what we observe in the field. We need to improve our ability to tie together biological understanding with understanding of the physical and chemical attributes of the system to allow better predictive capability of the effects of our activities. Research needs to contribute to defining what is, indeed, unreasonable degradation as it is so stated in statute. Finally, there are a number of monitoring programs which are required, either statutorily or by regulation, with which we need to couple research approaches.

The problems of interagency coordination, of course, are one of the issues that this panel is addressing. Indeed, in the area, of marine environmental quality, since so many agencies are involved, this is a subject of concern. Congress has indicated its intention to have coordinated planning within marine pollution research by passage of the National Ocean Pollution Research and Development and Monitoring Planning Act of 1978.

Although planning efforts have been going on, and some very interesting, insightful reports have been produced, at this state it is yet too early to say whether many of the resulting recommendations will be implemented. Indeed, Congress has a role in this as well. The Federal ocean pollution research plans that are developed must be carefully considered by Congress in its decisions regarding appropriations and agency responsibilities.

With that, Mr. Chairman, I will conclude my remarks. There are much more extensive comments that are in the written testimony, but in the interest of time, I will stop here.

Thank you.

[Statement of Dr. Boesch follows:]

Statement of Dr. Donald F. Boesch, Executive Director, Louisiana Universities Marine Consortium

I am an academic research scientist and administrator with the Louisiana Universities Marine Consortium, an organization of the state's 13 public universities for marine research and education. I am a biological oceanographer and have conducted basic and applied research on a wide range of subjects, including the organization and functioning of communities of marine organisms, the interactions of organisms and sediments, strategies of environmental impact assessment, and modifications of coastal and estuarine habitats. My research has encompassed estuarine and continental shelf and slope environments on the east and Gulf coasts, Australia and Asia.

In the conduct of this research, I have worked with several Federal agencies, notably the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the Department of the Interior, the Department of Defense (Army Corps of Engineers) and the National Science Foundation (NSF). In addition, I have become broadly familiar with the Federal marine science programs as a member of the Marine Board of the National Research Council, chairman of the Scientific Committee of Interior's Outer Continental Shelf (OCS) Advisory Board and an ad hoc advisor to NOAA, EPA, and NSF. Because of the diversity of this experience, in particular with agencies with an applied mission, my testimony will focus mainly on the prospects and limitations of applied marine research and the availability and coordination of Federal oceanographic assets, especially in research on marine environmental quality, an area in which most of the Federal agencies with marine programs are involved.

Although some of my comments will be critical, I want to express in the beginning my enthusiasm and optimism concerning the development of marine research in the next few decades. The accomplishments of oceanography today were unpredictable twenty years ago. Similarly, it is difficult to predict our future successes. However, there is a broad community feeling that we are on the threshold of substantial advances in our understanding and use of the oceans, largely as a result of tremendous technological developments and the fusion of disciplines of ocean science. This enthusiasm is captured in the NSF planning document, "Emergence of a Unified Ocean Science" and in the ongoing "Oceans 2000" study of the National Research Council's Board on Ocean Science and Policy.

Prospects for Marine Environmental Research

Research on marine environmental quality is distinguished by its societal importance, relevance to multiple functions of government, complexity, and its responsiveness to public, political and legal forces. Perhaps the principal use of the ocean, both now and in the future, is as the ultimate repository of waste products of human society. Yet we also wish to protect our long-term use of the other resources of the ocean at the same time. Exploitation of these other resources, whether fish, energy or minerals, may also affect environmental quality. Numerous federal, state and local agencies have interests and responsibilities concerning marine environmental quality (and thus sponsor research on the subject), be their objectives waste disposal, energy and minerals development, fisheries, transportation, defense or environmental protection. Just at the Federal level the bewildering array of agencies with a stake in marine environmental research is an acronym soup: DOD (COE, ONR), DOE, DHHS, DOI (MMS, FWS, USGS), DOT, EPA, NOAA, NRC, and NSF come to mind.

In addition to the bureaucratic complexity, there is the notorious environmental complexity which the research scientist must unravel. Our use of the ocean's resources interact and sometimes conflict. Environmental scientists are asked to sort these impacts out within environments which are poorly understood and highly dynamic. More than any other field of marine research that I know, research on marine environmental scientist. As a result they sometimes lose contact with active researchers, particularly those in basic research, and become preoccupied by the processes of administrative planning, budgeting and procurement.

Federal and agency policies governing the selection of performers of research also limit innovation in applied environmental research. Procurement processes can limit the input of non-governmental scientists in the design of research and discourage academic scientists from involvement because of narrowly defined scopes of work, rapid responses required and onerous requirements for proposal boilerplate. Contracting officers frequently adopt the attitude that research can be procured much like spare parts or printing services; rather, in most cases, it is scientific understanding rather than data products which is sought or should be sought. The result in many agencies has been that academic researchers are increasingly disadvantaged compared to private sector service companies. Scientists employed by such service companies often have few incentives to go beyond the stated tasks or to publish results in the open literature, i.e. to contribute to advances in the broader context of science. To be sure, I do not suggest that academic scientists be given preference, but I merely wish to indicate that the wealth of innovation resident in academia is being increasingly disenfranchized from applied marine environmental research by government policies. This is contributing to widening the basic-applied research gap discussed above.

The problems I have described are not peculiar to applied marine science, but I suspect probably occur in other environmental sciences. There are, however, some steps which agencies can take to enhance innovation in applied marine environmental research. Broader thinking and planning which cross the lines of activity-related interests (e.g. sludge dumping, oil and gas development, etc.) should be encouraged. The interagency planning efforts required by the National Ocean Pollution Planning Act of 1978 (P.L. 95-272) enhance broad assessments of marine environmental quality issues (Interagency Committee on Ocean Pollution Research, Development and Monitoring, quality is subject to the frequently changing and blustery winds of public concerns, political pressures and legal mandates which often direct or limit research to proximate rather than ultimate issues. The creeping sludge monster issue in the New York Bight (Squires, 1983) and the effects of discharges from exploratory oil and gas wells (National Research Council, 1983) are examples from my experience in which intense effort was focused too narrowly as a result of such pressures.

Research quality: the need for innovation

Applied marine environmental research is generally regarded as of inferior quality by the marine science community and, in my judgment, is not well coupled with basic research. In general, applied marine environmental research is not effectively assimilating the products of basic oceanographic research nor effectively utilizing state-of-the art approaches developed in basic research. A fundamental cause of this disjunction between basic and applied research is that there is relatively little community overlap among scientists who do basic and applied research. As a result, there are relatively few researchers in a position to transfer insights between these communities; the bulk of our intellectual talent is generally confined to the basic science community and is not being brought to bear on practical problems; and the lack of scientific rigor and innovation in applied research limits success in reaching goals, decreasing cost effectiveness in the long run.

The reasons for this disjunction between basic and applied research are cultural and institutional. Basic scientists believe that applied science will pose limits on their academic freedom to pursue research objectives; they are concerned whether the research can be adequately performed under pressures for quick answers and reporting deadlines; they find the scope of tasks defined by program managers as too narrow and constraining. Agency program managers find themselves in a bureaucratic climate with very different reward systems, flexibility and time constraints than the research

1981a). A recent evaluation within NOAA considered the magnitude of marine environmental quality problems and the level of research effort devoted to them and concluded that four areas are being underemphasized: eutrophication and oxygen depletion in coastal waters, toxic organic chemicals, coastal habitat degradation, and contamination of seafood products with human pathogens. The Administrator has directed that resources should be reprogrammed to more adequately address these issues. Such concerted attempts to step back, evaluate and redirect are commendable. The next step would be to view the issues from the environmental side of the matrix to identify processes important in ecosystem response to these human "agents." This perspective could be facilitated by greater involvement of basic scientists in the planning process. Through this mechanism and others (meetings and colloquia), scientists and research program managers in applied Federal agencies should be encouraged to increase their exposure to the basic science community.

Research planning should be opened to greater extramural input in order to enhance innovation. Science advisory and review committees composed of non-governmental scientists can be helpful in this regard. These may take the form of a standing advisory committee or an ad hoc panel convened by an agency interagency group or by an independent body such as the National Research Council.

An interesting model with which I am familiar is the so-called Petroleum Review conducted under the auspices of the Interagency Committee on Ocean Pollution Research, Development and Monitoring (COPRDM). In this review a panel of 15 scientists and environmental managers from outside of the Federal sector was briefed on the research programs of Federal agencies related to the environmental impacts of petroleum and OCS development during three regional meetings. The vast amount of material which had to be assimilated and the short time available limited the panel to rather general conclusions and recommendations (Interagency Committee on Ocean Pollution Research, Development and Monitoring, 1981b). Although the panel's assessments were, in some cases, vague and presumptious, the agency responses to criticisms (published with the panel report) were telling. One could easily see where nerves were struck—agencies often responded that the panel did understand their mandates and regulatory responsibilities.

Although the Petroleum Review was deemed "extremely valuable" by COPRDM, few of the panel's recommendations have been specifically met. I have also been involved in further planning in relation to the principal recommendation extracted from the panel report by COPRDM: an interagency research program to investigate the long-term, low-level adverse effects of OCS and other ocean use activities. Initially, a workshop was held to design the study plan, but the workshop was too brief for and adequate job. Subsequently, I have led a more considered planning effort which has involved preparation of extensive background materials and development of a coherent research strategy. This effort has just been completed, so it is too early yet to comment on its reception and implementation by the relevant agencies.

I also serve on a standing advisory committee concerning research on environmental issues of OCS development, the Scientific Committee of the Department of the Interior's OCS Advisory Board. This committee was initially appointed in 1979 and had just become familiar enough with the Department's programs to offer specific advice when, in 1982, it became essentially defunct as a result of controversies over political reviews of appointment of members. Relatively few of the recommendations of the committee were ever implemented and the committee has just been reactivated during the last few months. My opinion about the effectiveness of this standing (sometimes) committee, consequently, is not yet formed, although I note that other agencies, e.g. EPA, have scientific advisory committees which have functioned with some effectiveness for a longer time.

More open and flexible research solicitation procedures would also enhance innovation. Request-for-proposals which state general information needs and rely on the

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scientist to propose innovative approaches to meet these needs should be encouraged. There should be increased peer review at all levels--scopes of work, proposals and reports. Among the applied marine agencies, only EPA has a rigorous peer review system.

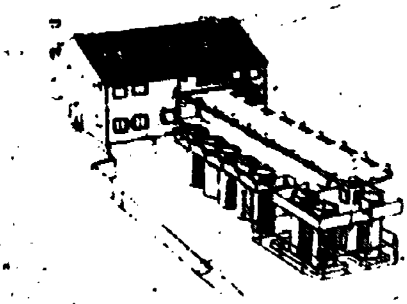
Challenges in research and monitoring

What should be our general goals for the next 10 to 20 years in marine environmental quality research? How can the needed advances be achieved? How can we efficiently and meaningfully assure that the marine environment is sufficiently healthy? Indeed, what constitutes its health?

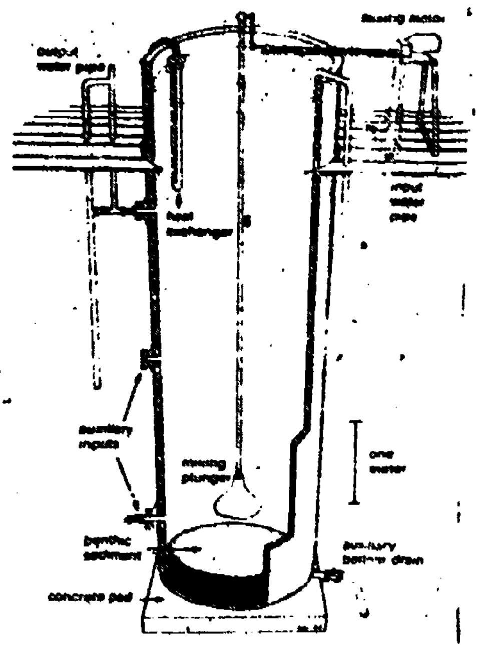
Environments of concern. We seem to shift emphasis periodically between coastal and oceanic environments. Historically, most marine pollution has been conducted in coastal and estuarine waters. Between 10 and 15 years ago, a new emphasis on continental shelf environments began to emerge with concerns over ocean dumping and OCS development. Now agencies such as NOAA and EPA seem again to be emphasizing estuarine and coastal research and monitoring. In addition, there are emerging concerns about man's influence on the global ocean, for example as a facet of the CO_2 build up. Where should our concerns be placed and do we run the risk of neglecting some environments by heavy emphasis on others? In my view, shifting emphases to coastal and estuarine environments is wise, simply because this is where the most pressing problems are. However, it is the pervasive degradation of estuarine and coastal environments as a result of eutrophication, habitat modification, and contamination with synthetic organics which should command attention rather than isolated "point source" impacts. Also, because of the extreme diversity of coastal environments, special consideration must be given to generalizing or transferring research findings; we cannot afford to exhaustively study all of the Nation's estuaries. At the same time, it now also appears that human society has the capacity to alter continental shelf ecosystems on a rather large scale (witness the oxygen depletion observed in the New York and German Bights and in the northern Gulf of Mexico). Continued shelf research is certainly required. In many respects our understanding of the ecology of the open ocean is better known than that of the continental shelves. Important advances in basic research have been made or are imminent in such areas as ocean basin-wide circulation and the vertical flux of materials which provide precisely the information required to understand anthropogenic influences on the open ocean.

Biological systems--Biology is usually the weak-link in understanding the effects of human activities on marine ecosystems. I don't think this is because biologists are particularly dimwitted, but it is a manifestation of the complexity of biological systems. There are different levels of organization (cells, tissues, organs, organisms, populations, communities) and different components of ecosystems (plankton, benthos, nekton). Just as these living systems are subdivided, so are Biologists. The components in biological systems must be much better integrated than the disciplines of biology or they would be in danger of extinction. In the context of marine environmental research, the need to better understand biological systems is apparent in the the difficulties in relating sublethal responses to stress observed experimentally to survival of the organisms, and organism survival to population success. This must be a goal of future research. Even within these limitations, concensus can exit among biologists about what are likely the most susceptible components to certain kinds of impacts. Frequently, it is wise to focus on the benthos because pollutants may be concentrated in bottom sediments and many benthic animals are sedentary. However, it is often also necessary to unravel the coupling between the benthos and the plankton to understand effects (e.g. eutrophication phenomena).

Prediction--Predictions in any quantitative sense are presently hindered by the weakness in relevance of laboratory-based experimental results (e.g. bioassays) to conditions existing in the natural environment, on one hand, and the inherently retrospective nature of field assessments, on the other. These approaches must be linked more effectively through a process sometimes called hazard assessment. The common denominator in this translation is a solid understanding of environmental processes which effect the actual exposure conditions. These processes have been poorly addressed to date. Another approach which has yielded insights which enhance prediction is the experimental containment of natural or near-natural ecosystems in microcosms or mesocosms. The Marine Ecosystems Research Laboratory (MERL) mesoscosms at the University of Rhode Island have shown that such experimental "ecosystems" can be maintained such that they behave like nature and respond in ways similar to nature when stressed. The MERL mesocosms have allowed the study of processes which underlie ecosystem response and are also suited to asking "what if" questions relevant to assessing new impacts and recovery of ecosystem following pollution abatement. There is a need for more such facilities strategically placed to represent major estuarine and nearshore ecosystems. Even OCS MERL's are within the realm of feasibility, based either on mobile or fixed structures. We will have no shortage of fixed structures in the Gulf of Mexico which are no longer producing oil and gas and must otherwise be removed.



The MERL experimental mesocosms at the University of Rhode Island.



Defining unacceptable damage—Virtually anything man does in the ocean or coastal zone has an impact, albeit infineteamal or immeasurable. Beyond that we must define what constitutes "unreasonable degradation" of marine ecosystems and their resources. This definition is ultimately set by society, but research must contribute to quantification of environmental degradation in two important ways: 1) determination of the significance of alterations of marine populations and their milieu to resources of value to society and continued functioning of the ecosystem, and 2) development of a better understanding of the recoverability of ecosystems and their resources.

Monitoring—"Monitoring" seems to be back in vogue again. In the late 1960's and early 1970's great optimism existed that environmental monitoring programs would be effective in providing an early warning system. Later in the 1970's, the bloom was off the rose as experience suggested that monitoring may be insensitive because of the great variation in space and time of natural ecosystems. Now one hears talk of national estuarine monitoring programs and of costly new compliance monitoring programs for sewage discharges exempted from secondary treatment standards under Section 301(h) of the Clean Water Act (P.L. 95-217). Monitoring means different things to different people. The Second National Marine Pollution Program Plan states that the role of monitoring "in the national program is twofold: on one hand it serves to warn against unacceptable impacts of human activities on the marine environment and, on the other, it provides a long-term data base that can be used for evaluating and forecasting natural changes in marine ecosystems and the superimposed impacts of human activities." In my opinion, these objectives are valid, but I know of no cases where we can confidently pursue monitoring in a strictly observational mode, i.e. as observing canaries in a mine. Rather monitoring programs should have research components (even though they may be small parts) in which cause-effect relationships can be experimentally investigated.

Interagency Coordination

The Ocean Pollution Research, Development, and Monitoring Act of 1978 (P.L. 95-273) was based on the finding that numerous Federal agencies sponsor, support, or fund activities relating to ocean pollution research and development and monitoring but that such activities are often uncoordinated and can result in unnecessary duplication. The Act directs NOAA, as the lead agency, and other appropriate Federal agencies to prepare a comprehensive 5-year plan for the overall Federal effort in ocean pollution research, development and monitoring. The first such plan published in the fall of 1979 was prepared in very short time, the Second Plan was dated September 1981 (but released in 1982). It was a positive effort to define relative priorities for Federal research and development. The Third Plan is scheduled for publication in 1985.

Although the interagency planning mechanism (COPRDM) itself is a significant advance in terms of encouraging interagency awareness, dialog and assessment of priorities, little evidence exists to date of implementation of the recommendations of the Second Plan. In addition to the Petroleum Review and subsequent planning efforts on the OCS long-term effects program discussed above, other interagency research planning efforts concern quality assurance of chemical analyses, ocean dumping of sewage sludge and industrial wastes, and disposal of radioactive materials. Under the Act, interagency coordination relies on good faith efforts and NOAA has no authority, budgetary or otherwise, over the programs of other agencies.

There remain problems caused by poor interagency coordination in marine environmental quality research which result in inefficiencies, possible duplication or even conflicts. For example, at least three independent Federal programs involve the physical oceanography off Southern and Central California (MMS, DOE and NSF). Differences in perspective and approach lead a few years ago to essentially an adversarial situation between MMS and EPA on assessment of the effects of drilling discharges. Worse than this, important problems may fall in the seams of agency jurisdictions and interests. Two examples from the northern Gulf of Mexico will illustrate my point.

DOE operates regional oceanography programs off Atlantic southeast, Atlantic northeast, Pacific northwest and Pacific southwest coasts. The programs focus on oceanographic processes relevant to understanding the transport of man-produced compounds (energy related) through the coastal ocean. The DOE programs have contributed significantly to understand the continental shelf environments and ecosystems and the research was highly regarded in the report of a recent National Research Council (1984) panel. There is no regional oceanographic program in the Gulf of Mexico in part because when one was proposed about 10 years ago, it was decided that the Bureau of Land Management (BLM) of the Department of the Interior, with its primary responsibility for oil and gas development and growing programs, would take that responsibility. However, BLM's programs have focused predominantly on undeveloped frontier areas rather than the heavily developing areas off Louisiana and Texas. Furthermore, BLM's (now MMS) programs have generally been descriptive and not process oriented. The net result is that oceanographic processes in this region, which is most influenced by energy-related activities and receives man-produced compounds from two-thirds of the continental U.S., have gone essentially unstudied.

The second example concerns the rapid deterioration of coastal wetlands and salt water intrusion in estuaries in Louisiana. An estimated 100 km^2/year (50 $miles^2$/year) of wetlands are being lost, amounting to 85% of the Nation's wetland loss rate. Federal research programs on the issue are notable by their absence—only the U.S. Fish and Wildlife Service and NOAA Sea Grant have been very involved. The MMS has claimed research on the subject outside of its responsibility, despite the fact that modifications to wetlands made to accommodate offshore oil and gas development have contributed to wetland loss.

Despite the limited accomplishments of the COPRDM planning process to date, continuation of interagency planning at the level is essential. The recommendations of the forthcoming Third Plan should be carefully considered in budget decisions by the President and Congress by implementing high priority programs and curtailing low priority programs. In addition, COPRDM with the assistance of non-government scientists should undertake bolder and longer range research planning. The coherence and aggressiveness of the NSF "Emergence of a Unified Ocean Science" document can serve as an example.

Interagency agreements or memorandums of understan[illegible]s of substantial coincidence of interest and responsibilities also enhance ef[illegible]se of resources. Agreements between EPA and COE concerning development of criteria for evaluating dredged materials for disposal and MMS and EPA concerning research on and regulation of drilling discharges are examples. On the other hand, interagency agreements which are little more than provision of a "maildrop" for pass through of funds, rather than a legitimate partnership based on common interests, do little to enhance coordination and efficiency. Many agency research and monitoring programs are operated regionally (e.g. MMS, DOE, and to a certain extent EPA, COE, NOAA). Consequently, the effectiveness of interagency coordination would be improved if there were regional interagency rountables to discuss common interests, air plans, pool research resources and maintain lines of communication with the research community in the region.

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Mr. PRITCHARD. Thank you, Dr. Boesch.

Next, we will have Dr. Robert Corell. We will go all the way through the panel, and then we will go back for questions.

STATEMENT OF DR. ROBERT W. CORELL, DIRECTOR OF MARINE AND SEA GRANT PROGRAMS, UNIVERSITY OF NEW HAMPSHIRE

Dr. CORELL. Thank you, Mr. Chairman.

Mr. Chairman, members of the Subcommittee on Oceanography, and friends of marine scientific research, there are many critically important issues that I would like to talk about today, but I will plan in this testimony to just address two ideas. First of all, some comments on deep sea research that has been facilitated by the research submersible *Alvin*, and some comments on high technology in the marine scientific world, particularly the role of robotics and intelligent systems in underwater application.

The deep submergence research vessel, *Alvin*, is a unique national asset which has facilitated profoundly important deep sea scientific research. *Alvin* is a Navy-owned, national oceanographic research facility, jointly sponsored by the National Science Foundation, the Office of Naval Research, and the National Oceanic and Atmospheric Administration. It is operated by the Woods Hole Oceanographic Institution and guided by a national review panel of which I am chairman. This committee is a component of the University-National Oceanographic Laboratory System, better known as UNOLS.

While seemingly complex in the interagency and interinstitutional arrangements, the overall guidance and management of this unique platform work well and, more importantly, in my opinion, the science produced is outstanding.

Alvin-supported scientific research programs have significantly altered our views of the Earth sciences, biology and life processes, and the chemistry of the physical and biological sphere. The past two decades have seen an explosion in the Earth and planetary sciences. The theory of plate tectonics has been unified from previously fragmented understandings. Hydrothermal activity has revolutionized our views of Earth crustal processes, the chemistry of the ocean, and of life processes themselves.

These are the kinds of scientific efforts that *Alvin* has been a major component within.

The management of *Alvin* is a well-structured interaction between a three-agency agreement that provides the basic support to the vessel, that is, the National Science Foundation, Office of Naval Research, and NOAA.

There is an incredibly well-honed team at the Woods Hole Oceanographic Institution that operates the vessel. The scientists in this community have learned how to use *Alvin* and use it well, and the UNOLS structure seems to be working well, in our opinion.

Alvin is a unique tool of science. I strongly recommend to this committee that a continued review of financial support to both operations and science are crucial to the health and vitality of deep ocean science. In my opinion, there should be more adequate financial support to all the cooperating agencies to fund research programs of excellence that require the *Alvin* and, further, to support more fully the research programs that can be conducted in the deep submersibles of the U.S. Navy, particularly, the recent addition of 6,000 meter capability in the *Seacliff*. These are important components, and the prospects for continued scientific achievement in *Alvin*, in our opinion, is strong.

Let me say a word or two about robotics and intelligent underwater systems, a big jump from *Alvin*, although *Alvin* is a high technology tool. The explosive development of complex and often sophisticated microcomputer and microelectric systems is just beginning to impact the ocean sciences and deep sea research. Microcomputer systems, with their attendant microelectronic and powerful software, provide means to conduct ocean research heretofore either difficult or impossible. Acoustic tomography, a sophisticated navigation systems, data acquisition, and signal processing systems, vision systems, remotely operated vehicles, and autonomous vehicles and platforms are all examples of demonstrated impacts from this technology.

These new technologies provide fascinating opportunities, not only for scientific research, but economic and industrial development in the oceanic sphere, and clearly impact on underwater efforts in the defense establishment. The research and development of smart and intelligent underwater systems is now underway but clearly in its early stages of evolution.

To give you some idea of the potential, let me describe one R&D program in one of our laboratories. We have been conducting basic scientific research in advanced technology development to create totally free-swimming, unmanned submersibles which can do useful work underwater. For example, we could show you a vehicle, totally free of any connection to the surface or to man, which can be dropped in the water, freely swim down to the sea floor, locate an underwater oil and gas pipeline, swim along the pipeline conducting an inspection mission such as a photo survey. This is all controlled by the intelligent computer system carried on board, and there is no physical or otherwise connection to the surface.

Similar vehicles of this nature have been developed to swim inside offshore drillng platforms and to visit preassigned locations and do photo surveys. There are accomplishments which have already been demonstrated in the laboratory. We are increasingly referring to these smart vehicles as underwater robots, workhorses of the underwater world.

The fascination in the marine science and academic world comes from placing this intelligence in freely mobile and totally autonomous underwater vehicles. Research is developing in this new field which we now call knowledge engineering. The problem for this committee is that the artificial intelligence world has developed to the point where we are entrapped with the idea that it will have real world applications, and we in the university laboratories have demonstrated its exciting potential, but there is a severe gap between what we can do in the laboratory and what is useful in the eyes of industry and the financial community.

That gap needs to be filled with development and research so that we can close the gap between the ideas of artificial intelligence and the application of knowledge engineering to underwater applications.

I urge this committee to foster such ideas by expanding the support to ocean science and technology and to obtain that measure of excellence in technology that has historically been characteristic of this Nation. In my view, it could give the United States an edge in science, an edge in economic and industrial development, and clearly impact our defense posture.

Mr. Chairman, thank you for the opportunity to share a few ideas. I would be pleased later to answer any questions which you or your colleagues might have.

[Statement of Dr. Corell follows:]

STATEMENT OF PROF. ROBERT W. CORELL, DIRECTOR OF MARINE AND SEA GRANT PROGRAMS, UNIVERSITY OF NEW HAMPSHIRE

Thank you, and good afternoon. Mr. Chairman, Members of the Subcommittee on Oceanography, and friends of marine research gathered here today to examine the status of marine research in the United States. It is a privilege and honor for me to be here. I am Robert W. Corell, a Professor of Engineering at the University of New Hampshire, where I also serve as Director of a research laboratory devoted to high technology in marine and oceanic systems. I also direct the Marine and Sea Grant College Programs at the University of New Hampshire. It is from these perspectives within the marine sciences and engineering community that I testify this afternoon.

Mr. Chairman, this hearing provides a unique opportunity, as you and the committee have provided the setting within which we can discuss broad perspectives on vitally important topics concerning the health and vitality of marine scientific and engineering research in the United States.

I want to begin my testimony by thanking you and the other members of this Subcommittee for the leadership you have demonstrated by establishing the legislative frame work for critically important national marine-related programs, such as, NOAA's marine and oceanic research efforts, programs for marine pollution, and the outer continental shelf (OCS) revenue sharing act to mention only a few. This leadership is deeply appreciated.

There are many critically important topics I would like to discuss. However, I plan to restrict my testimony to three topics, though, of course, I will be pleased to respond to any questions you may wish to ask. The topics are:

- Comments on deep sea research facilitated by the research submersible ALVIN.
- Comments on high technology in marine research, particularly the role of robotics and intelligence systems in underwater applications.
- Comments on international cooperation, particularly those that substantially influence the excellence of our own research programs and importantly impact our foreign policy.

Deep Sea Research and the Research Submersible ALVIN

The deep submersible research vessel, DSRV - ALVIN is a unique national asset, which has facilitated profoundly important deep sea research. ALVIN is a navy-owned national oceanographic research facility jointly supported by the National Science Foundation, the Office of Naval Research, and the National Oceanic and Atmospheric Administration. It is operated by the Woods Hole Oceanographic Institution and guided by a National Review Panel, of which I am Chairman. This committee is a component of the University National Oceanographic Laboratory Systems (UNOLS). While seemingly complex in the interagency and inter-institutional arrangements, the overall guidance and management arrangements work well, and more importantly, the science produced is, in my opinion, outstanding. I want to talk a little about the ALVIN program, and touch upon some of the science, (a one page summary describing the ALVIN and its support vessel ATLANTIS II is attached as an appendix to this testimony).

ALVIN was an idea born in the early 1960s, in many ways an idea that substantially preceded its time. The SPUTNIK era of the late 1950s, the tragic disaster of the Thresher, the acknowledged lack of substantive scientific understandings of the world's oceans, all conspired to nurture the idea of a deep submergence research submarine. The Navy, through a broad range of interests in research and technology development, gave the necessary support to bring the idea into reality. The history of ALVIN's evolution is a fascinating story in the history of science and technology. Complex and often frustrating steps were required in evolving ALVIN as a tool for science, to the stage where we are today. In the early 1970s, deep ocean submersible science spawned new ideas in the scientific world, best dated to the FAMOUS project. FAMOUS set the real context for the science we can discuss today, and provided the necessary ingredients for the three agency (NSF, ONR and NOAA) agreement that underpins the financial support for ALVIN operations today. The support for deep ocean, submersible supported science is now highly integrated into the ongoing programs of NSF, ONR, and NOAA, with several other federal agencies and programs also involved.

ALVIN's management is a well structured interaction between:

- Federal agency support of the National Science Foundation (NSF), the Office of Naval Research (ONR) and the National Oceanic and Atmospheric Administration (NOAA).
- The ALVIN Project Team at the Woods Hole Oceanographic Institution (WHOI).
- The scientists who need and use ALVIN, and,
- The ALVIN Review Committee of UNOLS.

Several years ago, a substantial effort was made by all concerned to enhance ALVIN's total effort by expanding our Long Range Planning activities. A key component was the so-called Submersible Science Study, which, along with agency planning, UNOLS, science community, and WHOI efforts, we now have world-wide capability available. We also have a carefully thought out process for establishing priorities and plans.

ALVIN supported scientific research programs have significantly altered our views in the earth sciences, biology and life processes, and in the chemistry of physical and biological sphere. ALVIN has worked primarily in the northern hemisphere, with work focused in the Western Atlantic and Eastern Pacific. During its almost 20 years of existence, it has evolved and changed extensively. (There is appended to this testimony a brief history of ALVIN, prepared by the Woods Hole Oceanographic Institution.)

ALVIN's operating depth (4000 meters) enables it to reach about 50% of the seafloor. The science down to 4000 meters still challenges and fascinates the U. S. Ocean Science Community. However, the ALVIN Review Committee is working with the U. S. Navy to expand our capabilities through the use of Navy submersibles, such as SEACLIFF (which operates to depths of 6000 meters), TURTLE and the NR-1. The advent of a 6000 meter SEACLIFF provides the potential for extending deep ocean science to regions that cover about 97% of the world's oceans, allowing us to look at vitally important subduction processes and other physical and geological processes in the deep sea.

The past two decades have seen an explosion in the earth and planetary sciences. The theory of plate tectonics has unified previously fragmented understandings, the hydrothermal activity has revolutionized our views of earth crustal processes, the chemistry of the oceans, and of life processes themselves.

Mr. Chairman, this is obviously a bright view of sea ocean scientific research supported by a unique tool - ALVIN. There are several summary comments I would like to make.

- The interagency cooperation between NSF, ONR and NOAA has been outstanding. There are efforts to expand that cooperation to other agencies, such as the USGS.

- The broad support ALVIN provides to the entire U. S. ocean science community is excellent. However, in my opinion, the ALVIN is operating at full capacity and a number of outstanding scientific programs cannot be conducted because the U. S. only operated one such vessel. The prospect of having access to the U. S. Navy's SEACLIFF, capable of 6000 meter operations is critical.

- ALVIN has been a keystone in many international cooperative programs, beginning with the FAMOUS program (the joint effort with the French). Oceanography lends itself to international cooperation, and ALVIN is no exception. If there is any difficulty, it is the fact that only two scientists can dive on this one-of-a-kind scientific tool.

- ALVIN is truly a unique tool of science, adequate financial support to both the operations and the science is crucial to the health of deep ocean science. In my opinion, there should be more adequate financial support to all the cooperating agencies to fund research programs of excellence that require the ALVIN, and to support more fully the research programs that can be conducted in the deep submersibles of the U. S. Navy, particularly the 6000 meter vessel SEACLIFF.

Robotics and Intelligent Underwater Systems

The explosive development of complex and often sophisticated microcomputer and microelectronic systems is just begining to impact the ocean sciences and deep sea research. Microcomputer systems with their attendant microelectronics and powerful software provide the means to conduct oceanic research heretofore either difficult or impossible. Acoustic tomography, sophisticated navigation systems, data acquisition and signal processing systems, vision systems, remotely operated systems (i.e., ROVs) and autonomous vehicles and instrument platforms are all examples of the impact of this technology. The impact of this technology in the future will most likely be in the use of intelligent systems, robotics and related information sciences. These new technologies provide fascinating opportunities, not only for scientific research, but economic and industrial development, and defense. The research and development of "smart" or "intelligent" underwater systems is now underway, though clearly in the early stages of evolution. To give you an idea of the potential, let me describe a research and development effort underway in our laboratories at the University of New Hampshire. We have been conducting basic engineering research and advanced technology development to create totally free-swimming, unmanned, submersibles which can do useful underwater work. For example, we could show you a vehicle, totally free of any connection to man or the surface, which can be dropped into the water, freely swimming down to the seafloor and locating an underwater oil/gas pipeline, and then swimming along the pipeline conducting an inspection mission, such as a photo-survey. All this is controlled by an intelligent computer system carried on-board the free-swimming, unmanned submersible. A similar vehicle, can be placed in the water, several hundred yards away from an offshore drilling platform, and using the "intelligence" on-board the vehicle, it can "swim" inside the complex structure and visit pre-assigned areas for photo-survey or other inspection purposes. These developments have been accomplished and we could show you film of the vehicle doing these things. We are increasingly referring to these "smart" underwater systems as robots, workhorses of the underwater world much like the industrial robots of the manufacturing industries.

Robotic systems for underwater applications are a new and emerging field of technical activity. There are many exciting developments in this underwater robotics field, where totally autonomous vehicles are being designed and developed to:

- survey underwater pipelines
- inspect offshore drilling rigs
- measure the topography of the underside of the polar ice cap
- photograph the deep ocean seafloor
- conduct bathymetric surveys in the deep ocean or in ice covered waters
- serve as an autonomous instrument platform for acoustic or other oceanic research
- serve as test-beds for hydrodynamic research, such as laminar flow vehicle systems

- military systems, including surveillance, weapon systems, and early warning detection.

This list is not inclusive, but provides some insight into the scope of applications already encompassed by the underwater robotic vehicle.

The areas for new research and technological advances for underwater robotic vehicles will most likely be:

- Applied artificial intelligence and knowledge engineering
- Microelectronics/computer hard and software systems
- Navigation, guidance and positioning
- Reliability
- Energy sources to power systems
- Communications
- Vision systems for free swimming autonomous vehicles or platforms

There are other technologies where the field is already mature and rich with applications. These include:

- Vehicle dynamics and control
- Data acquisition, processing and data base systems
- Materials
- Manipulator systems, and other work systems

These two major classes or areas of technologies are rapidly converging to form the basis for underwater robotic systems development, both vehicles and non-mobile platforms.

The fascination in the marine science and academic world comes from placing "intelligence" in a freely mobile and totally autonomous underwater vehicle or platform. This research is developing a new field of study called "knowledge engineering", which is simply the engineering application of the much talked about field of artificial intelligence. The impact on ocean scientific research is already being felt. This field is one that does lend itself to industrial and international cooperation. Cooperative research and development programs have been established between universities, such as ours, and major U. S. corporations. Further, international cooperative efforts are also underway, with the British, the French, and the Italians being foremost in this regard.

The major purpose for sharing these perspectives are two-fold:

- To outline the fact that laboratory-developed prototype underwater robots, which can do useful work, are a demonstrated reality.

- To indicate that basic engineering and advanced technology research in underwater robotics, based in a University environment, is only in the early stages of development. Most importantly, increased support is required before we can close the "gap" between the theoretical concepts of artificial intelligence and the practical application of knowledge engineering to operational systems in industry, government and defense.

The second issue, is critical, and deserves a little more discussion. Artificial intelligence has developed to the point where industry and government can see the incredible impact of its application to "real" world problems. We, in the university laboratories, have demonstrated that exciting potentials do exist. The gap is financially induced. The body of knowledge is immature, undeveloped in the eyes of industry and the financial investment community. Industry is excited by these potentials, but the needed research from their point of view is "too basic". Hence, the "science" behind "knowledge engineering" cannot yet serve the practical needs of industry or the Navy. Research, often cooperative between university laboratories and industry, is required. It is my view that the federal research support is the key to bridging this gap. The potential to industry and the defense establishment is incredible. I urge this committee to foster such ideas by expanding the support to ocean science and technology and for obtaining that measure of excellence in technology that has historically been the characteristic of this Nation. In my view, it could give the U. S. an edge in science, in economic and industrial development, and in our defense posture.

International Cooperation in the Marine Sciences

This subject has been discussed, competently by others on this panel. Therefore, I will speak only briefly on the topic.

I have been privileged to serve on several marine science Panels, which visited countries like the People's Republic of China, the Republic of Indonesia, and others. These Panels were components of official bi-lateral agreements between the U. S. and these other countries. It is my view that these efforts are critically important to the quality of our scientific research programs world-wide, and to our foreign policy.

First, the almost universal application of the 200 mile offshore jurisdictional arrangements, demands that we establish effective working arrangements with virtually all coastal nations. The science of the oceans knows no such 200 mile limitations. However, to work in those waters requires effective relationships between those countries and ours. In my view, there is no better way than to work first scientist-to-scientist, with government-to-government following, because this fosters mutually shared goals and objectives.

Secondly, from my visits and observations, modest investments in the marine science programs of our sister coastal nations can be effective tools of foreign policy. For example, the Science and Technology Agreement with the People's Republic of China has enabled us to have Chinese scientists in this country for extended periods of time. First hand observations suggest that the interactions are mutually beneficial. For

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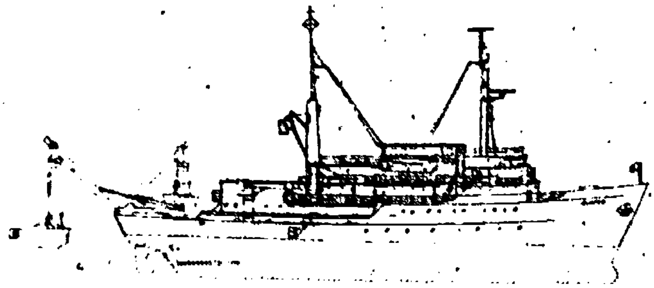
example, one exchange scientist/engineer from the People's Republic of China has enabled the National Bureau of Oceanography in the People's Republic of China to expand their technological base for a developing oil and gas industry, which they believe is critical to the future. The participants in the development of those new activities are predominately U. S. corporations. Hence, we too, benefit. In my view, such partnerships growing out of science, is an excellent component of our foreign policy. Maintaining the posture in our foreign policy, through scientific exchange, appears to me to be profoundly effective for both parties.

My purpose in mentioning these ideas is simply to urge your Subcommittee to integrate international marine scientific research programs into foreign policy legislation, using A.I.D., bi-lateral agreements, and the basic research support programs in the marine sciences available from NSF, NOAA, ONR and other agencies.

Mr. Chairman, thank you for this opportunity to share ideas with you. I would be pleased to answer any questions which you or your colleagues might have.

Appendix I

A Description of the DSRV ALVIN and its Support Vessel R/V ATLANTIS II



DESCRIPTION OF DSRV ALVIN

Length: 7.6 meters (25 feet)
Beam: 2.4 meters (8 feet)
Draft: 2.1 meters (7 feet) surfaced
Full Speed: 1 1/2 knots
Cruising Speed: 1 knot
Cruising Range: 5 miles submerged
Displacement: 16 knots
Endurance: 72 hours
Normal Dive Duration: 6-10 hours
Depth Capacity: 4,000 meters (13,120 feet)
Complement: 1 pilot, 2 scientific observers

Propulsion: Large stern propeller, 2 small side lift propellers which can be rotated and separately reversed.

Ownership: The submersible ALVIN is a Navy-owned national oceanographic facility jointly supported by the National Science Foundation, the Office of Naval Research and the National Oceanic and Atmospheric Administration and operated by the Woods Hole Oceanographic Institution.

Navigation: Gyro compass and gyro repeater; magnetic compass; bow mounted horizontal scanning sonar system; indicators for depth, speed, list, trim and variable ballast; echo sounder; battery voltmeters, ammeters and ground detector; five viewpoints.

Electrical Power: Three banks of lead-acid batteries, 60 and 30 volt DC systems, 40.5 KWH total. Limited amount of 115 volt 60 cycle AC power.

Communication: Sonar telephone (voice or code); marine band (VHF) radio.

Other Features: The submersible is designed to be versatile with respect to the weight, space and power requirements of portable scientific equipment in order to meet the differing needs of scientists using the vehicle. Scientific equipment which remains on board most of the time includes two remotely controlled mechanical arms and associated sample trays, 35 mm film cameras and associated strobe and incandescent lights, closed circuit video system with recorder, water temperature monitor, current speed and precisions depth indicator.

A precision navigation system is also available which will allow accurate positioning of the submersible at any time during a dive series. This system and other specialized equipment such as hard rock samplers, magnetometer, precision temperature sensors and analog or digital data logging equipment are available for use with ALVIN, but require some additional funding for installation and operation.

DESCRIPTION OF R/V ATLANTIS II

Built: 1963
Length: 210 feet LOA (64 meters)
Beam 44 feet (13 meters)
Draft: 16 feet (5 meters)
Gross Tonnage: 1,529 tons
Displ.: 2,300 L tons
Crew: 25
Scientific Personnel: 25

Main Engines: Two GM 12-567E diesel engines driving through reduction gears with variable speed, Hydraulic clutches. 2,000 shp.

*Bow Thruster: 250 hp transverse tunnel thruster. DC motor driving from main gear P.T.O.

Ships Service Generators: Two 480/120 volt AC 300-KW generators driven by CAT 353 diesel engines.

Propellers: Twin screw: 3 fixed blade; bronze.

Ownership: Built under grant from NSF. Conditional title rests with W.H.O.I.

Speed: Cruising: 11.5 knots
Full: 13.5 knots
Minimum: Dead slow

Endurance: 45 days
*Fuel Capacity: 151,000 gallons
Range: 13,5000 miles

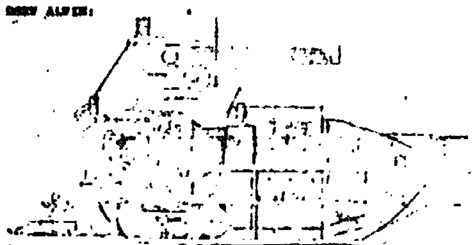
Laboratories: wet - 480 square feet
dry (4) - 4,300 square feet

Sewage System: Two type III holding tanks;
Five to ten days endurance.

Ship is equipped for full range of oceanographic observations and work. One trawl winch: 30,000 feet 1/2" cable. One hydrographic winch: 30,000 feet 3/16" wire. One CTD winch 27,000 feet 0.303" cable.

*A proposal needs to add a submersible handling system for ALVIN support, SEA BEAM system, and new 700 h.p. trainable bow thruster. If accomplished, fuel capacity will be reduced to 99,200 gallons and cruising range to 12,000 miles.

DSRV ALVIN:



Appendix II

A Brief History of the

ALVIN Program

BRIEFS OF ALVIN HISTORY FROM JUNE 1964 TO THE PRESENT........

1. ALVIN commissioned at Woods Hole on 5 June 1964.
2. June 1964 thru October 1964 - 77 dives in Woods Hole Harbor, Buzzards Bay and Vineyard Sound for shakedown, testing of submersible and equipment and training of operators. Dives progressively deeper from 12 feet to 65 feet. Three pilots were trained to operate ALVIN during this period.
3. Extensive overhaul followed test and training period. Tender, R/V LULU (original name DSRVT-1), was built and sea trials conducted during the ALVIN overhaul period.
4. LULU, with ALVIN aboard, towed to Port Canaveral Florida for deep trials and testing May 1965.
5. Deep trials in and around Port Canaveral Florida, New Providence Island Bahamas and Bermuda during period May 1965 thru September 1965. 29 dives were conducted including the unmanned, tethered drop to 7500 feet. Manned dives were conducted to 6000 feet. Many minor (and several major) problems were corrected during this period.
6. September 1965 - return to Woods Hole aboard LULU (under tow) for overhaul.
7. Early 1966 Air Force B-52s collided over Spain losing a H-bomb in the Mediterranean off Cartagena Spain. ALVIN was called. Late January 1966 ALVIN with her support vans were loaded into Air Force cargo aircraft and flown to Rota Spain.
8. During next three months ALVIN searched the ocean floor off of Cartagena for the lost H-bomb operating from a Navy LSD. Bomb was located for the first time on March 15 1966 but subsequently lost when attempting to attach lift lines. Bomb slid down-slope to deeper water - search continued.
9. Bomb was relocated on April 2 1966 by ALVIN and finally recovered on April 7 1966. ALVIN returned to Woods Hole, in the LSD, for overhaul.
10. August 1966 transit to Bermuda & Argus Island for inspection work on the Artemis Range for the U.S. Navy - 9 dives.
11. Transit to Bahamas, Tongue of the Ocean, late August to work for the Navy on the AUTEC range and for NAVOCEANO - 29 dives.
12. Return to Woods Hole October 1966 for overhaul of ALVIN and LULU.
13. Return to the Bahamas in May 1967 for additional work in TOTO for NAVOCEANO and subsequent transit north with geology and biology dives on the Blake Plateau and off of Cape Charles. During dive #202 on July 6 1967, ALVIN was attacked by a swordfish on the bottom at about 2000 feet. The fish became trapped in ALVIN's skin and was brought back to the surface intact. Arrived Woods Hole late August 1967.
14. After brief upkeep period, ALVIN/LULU returned to sea for a long series of dives south of New England in the Canyons and along the continental slope for geology, biology, thermal studies and sound measurements. On dive #209, in the Hydrographer's Canyon area, a Navy F6F aircraft was found, photographed and surveyed. It was later identified as being lost overboard from a carrier in 1944 (pilot was saved). On dive #224 September 24 1967, the mechanical arm was lost

during a rough recovery. The arm was subsequenty found and recovered on dive #236, October 15th, reconditioned and reinstalled. Damage was minimal.

15. Last dive 1967 on 24 October for USN/USL for ALVIN sound measurements. Commenced overhaul.
16. April 1968 to Provincetown MA for post-overhaul check-outs and VIP indoctrination and orientation. Four additional dives were made in and around Provincetown harbor to observe submerged whales.
17. Recertification of submersible and pilots in June 1968 followed by short series of biology and geology dives south of Martha's Vineyard on the continental slope.
18. August 1968 transit to the Azores inside USS SPIEGAL GROVE - Navy LSD.
19. August 9 thru September 3 1968 12 dives for USN/USL surveying tops of sea mounts for new Navy range.
20. Return to Woods Hole mid-September for short series to evaluate navigation system for NAVOCEANO followed by another short biology series south of Martha's Vineyard.
21. During launch for dive #308 on 16 October 1968 ALVIN's cradle support cables failed and ALVIN slid into the water and sank to the bottom in 1535 meters of water. Only casualties were bruises and a sprained ankle on the pilot. ALVIN stayed on the bottom almost a full year until she was successfully recovered by the DSV ALUMINAUT and R/V MIZAR on labor day 1969.
22. After a year-and-a-half overhaul ALVIN made her first post-loss dive, #309, on May 17 1971, followed by a series of 14 dives in Woods Hole Harbor and off of Provincetown to check and test the rebuilt submersible. Some VIP dives were also made during this series for NOAA, ONR, NAVSHIPS and SUBDEV-GRU ONE.
23. Mid June 1971 a biology series was commenced during which a permanent bottom station was established on the continental slope south of Martha's Vineyard. The station has been regularily re-visited at least once each year since.
24. July 1971 long series of dives in the Gulf of Maine for geology and physical oceanography followed by return to the Woods Hole area for biology on the newly established bottom station. Dr. Ruth Turner was ALVIN's first female scientist on dive #345 on August 13 1971.
25. Second series in the Gulf of Maine early September for ARPA and ONR geology and navigation.
26. Late September 1971 transit to Florida for a series of geology dives in the Straits of Florida for NOAA and ONR. On dive #364 ALVIN was attacked and hit by a large blue marlin while on the bottom off of Grand Bahama Island. The fish did some damage to the underwater lights and sail and much damage to himself.
27. Return to the Tongue of the Ocean in early November 1971 to work for ARPA and the AUTEC range. This series continued until 9 December when transit back to Woods Hole was made.
28. Overhaul until early May 1972 followed by two dives for trim and test and 10 dives testing new rock drill in deep water.
29. Biology on the bottom station early June 1972.

30. Hudson Canyon geology & biology series late June 1972 for NOAA followed by return to the Gulf of Maine in July. This series was for geology and to test the new ALVIN navigation system recently perfected. ALVIN's northern-most dive was #428 on 23 July at 43-42N.
31. Return to Woods Hole late July for a short upkeep period.
32. Bottom station for biology mid-August to deploy new experiments and recover some placed previously followed by an additional dive series in the Gulf of Maine for further testing of the new navigation system.
33. September & October 1972 - geology in the Hudson Canyon and biology at the permanent bottom station, continental shelf and slope.
34. October 1972 - navigation experiments with the new ALNAV system and tests with the rock drill.
35. Spring 1973. A new titanium pressure hull and variable ballast system were installed in ALVIN. Hull was furnished by the Navy and the ballast system built by NSRDC Annapolis.
36. ALVIN made 5 simulated dives to 12,000 feet in the NSRDC test tank - three unmanned and two with three persons aboard. The final 12,000 foot dive in the tank officially certified ALVIN as a 12,000 foot submersible.
37. Balance of 1973 - tests with new pressure hull and systems, rock drill & rock hammer tests, training and orientation dives.
38. Early 1974 work for AUTEC in the TOTO ranges. Biology and and the establishment of new deep Bahamian bottom stations.
39. February thru May 1974 training dives for FAMOUS scientists including 8000 and 10,000 foot test dives.
40. Summer 1974 - FAMOUS dives on the Mid Atlantic Ridge and NUSC work on the Azores Range.
41. August 1974 - dives on seven north Atlantic seamounts enroute back to Woods Hole.
42. Fall 1974 - NOAA dives on bottom station & continental slope south of Cape Cod.
43. October 1974 thru March 1975 - extensive overhaul.
44. April & May 1975 many biology dives throughout the Bahamas, geology around Grand Bahama Island and work for NUSC AUTEC.
45. Blake plateau biology dives enroute back to Woods Hole.
46. June thru September 1975 - slope and shelf biology and geology. NOAA radioactive waste dump survey and considerable biology at the permanent bottom station. Establishment of a new deep 12,000 foot station south of Cape Cod.
47. October thru December 1976 - upkeep for the submersible.
48. January & February 1976 - check-out, training and certification dives out of Guantanamo Bay Cuba and NSF geology in the Cayman Trough south of the Cayman Islands. ALVIN certification for 4000 meter max dive depth.
49. March & April 1976 - inspection, search and survey work for NAVFAC, NADC and TRACOR in the St. Croix area. Geology along the continental margin and outer Bahamas. Inspection and salvage work for NUSC, NADC & NAVELEX in the TOTO area.
50. Return to Woods Hole for short upkeep period.
51. Biology on the continental shelf, slope and the canyons

south of Cape Cod during June and July 1976.

52. During August 1976, the radio active waste (RADWASTE) site off of New Jersey was again surveyed and inspected and several waste drums recovered.
53. Return to Woods Hole for short overhaul.
54. Transit south December 1976 for inspection and survey work for NUSC AUTEC and biology throughout the Bahamas.
55. Transit to Panama and Canal passage (for the first time) and geology work in the Galapagos Rift February & March 1977. During the Galapagos dives (and the East Pacific Rise dives which will follow) one of the major discoveries was an abundance of warm water animal life on and in the immediate proximity of the warm water vents. Since no light can penetrate through the deep waters, the scientists concluded the animal chemistry is based on "chemosynthesis".
56. Return thru the Canal for second series in the Cayman Trough (continuation of geology investigations). During this series the Nicaraguan earthquake occured and was plainly felt by ALVIN while submerged. April 1977.
57. Return to the Bahamas and TOTO late April 1977 for geology & biology. Return to Woods Hole late May.
58. June through September 1977 - extensive biology at the bottom stations, slope, shelf and canyons south of New England.
59. October 1977 through April 1978 - major overhaul for ALVIN and LULU. New titanium frame was installed in ALVIN.
60. May & early June 1978 recertification and geological work along the U. S. east coast. Balance of June continuation of of the radioactive waste investigations at the dump site off of New Jersey including waste drum recovery.
61. July & August 1978 - second trip to the mid-Atlantic ridge for a continuation of "Plate Tectonic geology on the plate spreading centers.
62. September 1978 biolgoy off the New England coast.
63. In early October ALVIN & LULU returned to the Bahamas and conducted many biology & geology dives throughout the area.
64. Early January 1979 transit to Panama followed by three biology and geology cruises to the Galapagos.
65. April & May 1979 - first geology trip to the East Pacific Rise at 21 degrees north off of the Mexican west coast during which many hot water vents (350 deg. C) were discovered.
66. June through September 1979 - many biology, geology, physical oceanography and chemistry cruises around the San Diego -- San Clemente area.
67. Remainder of 1979 transit south along the central American coast with geology, biology and chemistry dive series at the Tamayo Fracture zone and return to the East Pacific Rise at 21 degrees North followed by the fifth cruise to the Galapagos.
68. In early January 1980, ALVIN and LULU returned to the Galapagos rift for the sixth time primarily for geology investigations. ALVIN's 1000th dive took place during this cruise.
69. February 1980 - Canal transit and return to Woods Hole for overhaul.

70. May 1981 - recertification for ALVIN and pilots.
71. June & part of July 1980 - return to the Mid-Atlantic Ridge and the Kane and Oceanographer's Fracture Zones for extensive geology. Return to Woods Hole.
72. July through mid-October geology and biology on the bottom stations, continental slope and shelf for NSF and USGS.
73. Mid-October through the balance of 1980 transit south diving along the East Coast, Bahamas, TOTO and St. Croix areas. Geology and biology for NSF and filming for the BBC.
74. January & February 1981 extensive work in the St. Croix area, training for IMI Japanese, search & recovery for NADC and NWTF, engineering dives for WHOI and biology/geology for NSF and the Joint Agreement (NSF, ONR & NOAA).
75. Return to Woods Hole mid-February for overhaul until June 1981.
76. July 1981 - after overhaul and recertification, biology and geology dives for BLM in the canyons south and east of Cape Cod.
77. Late July transit to Panama, Canal transit and geological trip to the Galapagos area.
78. September through December 1981 biology series in the Panama Basin, geochemical investigations at the EPR 21 degrees north and a biology cruise to the hot vent area.
79. Early January 1982 cruise to the Guaymas Basin and another geology trip to the hot vent area at 21 degrees north.
80. Mid-February 1982 transit north to the San Diego area.
81. Many short cruises out of San Diego during the remainder of February and until early April for biology and chemistry followed by transit back south to the EPR 21 north area.
82. Balance of April through May, cruises out of Mexican ports to the EPR hot vents for biology and chemistry. Walter Cronkite made dive #1211 to the hot vents during this period.
83. Return to the Panama Basin for biology in June 1982.
84. Late June through July 1982, Canal passage and long transit to the Mid Atlantic Ridge TAG area for biology.
85. August & September 1982 transit back to Woods Hole followed by cruises to the continental slope and shelf south of Cape Cod for biology, geology and corrosion studies.
86. Remainder of 1982 - transit south to the Florida Straits for geology followed by biology in the Northwest and Northeast Providence Channels and transit to St. Croix. A series of engineering dives for WHOI and finally geological survey of the slope south of Puerto Rico for the University of Puerto Rico.
87. Mid December 1982 - transit back to Woods Hole for overhaul.
88. From the December arrival until June 1983 a major ALVIN overhaul took place at Woods Hole. During the same time, work on the Research Vessel ATLANTIS II continued, preparing her for her new role as mother ship and tender for ALVIN. These extensive modifications were conducted during ATLANTIS II's regular "mid-life refit". ALVIN's major modifications were structural provisions to provide a single-point lift. The A-II newly installed A-Frame will be used to lift ALVIN into and out of the water from the single attachment point.
89. During late June 1983 ALVIN conducted trim and test dives

out of Woods Hole and was recertifed on June 29 to 4000 meters by the Navy. LULU was used as tender for these dives.

90. July and August 1983, ALVIN & LULU conducted several short cruises out of Woods Hole for corrosion experiments, filming for Japanese TV, and biology. Sponsors were NSF, KAPL, WHOI and the Joint Agreement.

91. Balance of 1983 final preparations for the ALVIN/ATLANTIS II merger. ALVIN and all of her support equipment and supplies were moved aboard AII. Modifications to the submersible were completed and installation and check-out of AII's A-Frame and other support gear completed.

92. January & early February 1984 final testing of A-II's new support gear including a number of simulated ALVIN launches and recoveries using a test tank. Final sea preparations.

93. Transit to Charleston S.C. early February. Following harbor tests with the new A-Frame (including first actual ALVIN launch & recovery) geology cruise to the Blake Plateau commenced. Several rough water recoveries were made at sea proving the A-Frame system will work under other than ideal conditions.

94. Balance of February a short cruise for geology in the Florida Straits off of Grand Bahama Island and some work for NUSC AUTEC in the Tongue of the Ocean. Transit to Tampa Florida.

95. Geology/biology cruise out of Tampa on the West Florida Escarpment in the Gulf of Mexico during which a series of bottom cold water vents were found. This was another major discovery - no vents were expected in this area. Transit to Panama and Canal passage mid March 1984.

96. Biology cruise to the Panama Basin late March & early April for WHOI biologists. This was a continuation of Basin studies commenced earlier.

97. Transit north to Acapulco Mexico to change scientists and load gear for the next geology cruise to the EPR hot vents mid April. During this cruise ANGUS discovered a new vent field to the south of the dive area. ALVIN & AII visited the new vents.

98. Second EPR vent trip commenced mid May 1984 with WHOI biologists aboard. Return to Manzanillo Mexico for the next group of Washington University and WHOI scientists and preparations for the next cruise to a group of sea-mounts in the same EPR area. This cruise commenced on 29 May 1984.

Mr. STUDDS. Thank you, Dr. Corell.

Let me apologize to the panel. Precision, I guess, is more a characteristic of your profession than of ours. I was summoned by higher powers, but we will make up for it in the questioning.

Congressman Pritchard, would you like to greet the gentleman from Washington?

Mr. PRITCHARD. Thank you.

Mr. Chairman, it is nice to know that somebody from our committee gets to the Speaker's office. I congratulate you for at least being called. I haven't been called to the Speaker's office for a long time.

Mr. STUDDS. How much is it worth to you? [Laughter.]

Mr. PRITCHARD. I would like to welcome Dr. Heath, who has recently joined the faculty of the University of Washington. He is dean of the college of ocean and fisheries sciences and, coming from my district, it is a particular pleasure for me to welcome you, Dr. Heath.

Dr. HEATH. Thank you, Mr. Pritchard.

Mr. STUDDS. Dr. Heath.

STATEMENT OF DR. G. ROSS HEATH, DEAN, COLLEGE OF OCEAN AND FISHERY SCIENCES, UNIVERSITY OF WASHINGTON, SEATTLE, WA

Dr. HEATH. Thank you, Mr. Chairman.

In addition to being dean of the college of ocean and fishery sciences at the University of Washington, which is one of the two oldest and currently is the largest U.S. educational program of its kind, I am also the chairman of the board of governors of Joint Oceanographic Institutions, Inc. which Dr. Baker has just described. Finally, I will shortly take over the chairmanship of the National Academy of Sciences' Board of Ocean Science and Policy. This Board provides, and is able to provide, scientific advice to a number of Federal agencies.

My personal scientific expertise is in the marine geochemistry of deep sea sediments. Some of my recent research has been concerned with deep sea manganese nodules and with the assessment of the environmental and scientific feasibility of subseabed disposal of high-level radioactive wastes.

I appreciate the opportunity to address the questions you have raised. It is clear that we are entering a new era of marine research. The availability of oceanographic satellites, which have been supported by NASA, NOAA, and the Navy, will lead to our first global view of the ocean. Such a view is indispensable if we are to understand, for example, the physics of the ocean and predict its influence on climate and on man's carbon dioxide experiment.

A global view also will give us a picture of the yield of the oceanic crop of phytoplankton, the microscopic plants that support most higher forms of life in the ocean. Such a picture is one of the crucial inputs to scientifically sound fisheries management.

In my own area of research, we are beginning to decipher the way in which both the natural and artificial chemicals that enter the ocean interact with plants, animals, suspended particles, and the oceanic circulation before they are buried beneath the sea floor. Such knowledge holds clues to the fate of pollutants, to the reconstruction of past climates, and to the ultimate carrying capacity of the oceans.

Our ability to meet the challenge of the next decade and beyond is open to question at the moment, however. Dr. Baker has pointed to our inadequate and decaying infrastructure. I support his conclusions. We have been living off the capital investments of the 1960's for too long.

Both mission and research oriented agencies of the Federal Government draw on the intellectual pool that is found in our great universities. These agencies must provide the infrastructure to keep the pool from drying up.

In the past, there has been a tendency to avoid such commitments because, for example, a single piece of equipment or a specific student fellowship is not uniquely associated with some short-term mission need. Such a perspective can only lead to disaster in the long term. The antiquity of our buildings and our research equipment, both at sea and ashore, bear witness to the sacrifice of long-term vision for short-term expediency.

What is the cure? The simplest would be the provision of block funding to oceanographic institutions to rebuild the infrastructures described by Dr. Baker and to prepare for the future. Because academic institutions have corporate memories and visions that are long, in a political context, such institutions can allocate resources to ensure the future health of oceanography in a rational way. The two decades after the war, when block funding provided a foundation for the oceanographic research establishment that still leads the world, provide evidence of the soundness of such a mode of funding.

Unhappily, virtually every component of the Federal establishment now acts, or is compelled to act, as though it were able to manage long-term scientific planning better than the institutions whose future depends on such planning. This situation will be difficult to correct, but support for the infrastructure as described by Dr. Baker and for broad, long-term research programs, such as studies of ocean climate, of chemical and biochemical reactions in the oceans, of the coastal regions where land and sea interact, of the factors that control the survival of juvenile fish and their prey, of the mid-ocean hot springs that are forming mineral deposits today, and of the geologic processes that form the edges of the ocean basins which contain so much of our petroleum deposits will do much to ensure that the potential advances of the rest of the century do, in fact, become reality.

Finally, we must appreciate and take advantage of the differences between Federal and university oceanographic laboratories. The Federal laboratories have the ability to mount and sustain very extensive and long-term observational programs. Such programs are difficult to sustain in the university setting, yet are crucial to studies of climate and fisheries, for example. The proper preservation of good data in a readily accessible form also is a task that only an organization like NOAA can undertake.

Academic institutions, on the other hand, have a continuous supply of bright, young intellects in the form of graduate students and postdoctoral researchers who interact with experienced faculty to produce most of the new ideas about the ocean. The experiments that test these ideas rarely last more than a decade, yet form the basis for our long-term understanding, care, and exploitation of the oceans.

The complementary roles of Federal and university laboratories must be recognized and maintained. If either falls into disarray, we cannot have a healthy program of marine research in this country.

Thank you.

[Statement of Dr. Heath follows:]

STATEMENT OF DR. G. ROSS HEATH, DEAN, COLLEGE OF OCEAN AND FISHERY SCIENCES, UNIVERSITY OF WASHINGTON

Mr. Chairman, I am G. Ross Heath, Professor of Oceanography and Dean of the College of Ocean and Fishery Sciences at the University of Washington in Seattle. At present, I am also the Chairman of the Board of Governors of Joint Oceanographic Institutions, Incorporated, an association of U.S. "blue water" academic oceanographic institutions. Finally, I will shortly take over the chairmanship of the National Academy of Sciences' Board of Ocean Science and Policy. My scientific expertise is in the marine geochemistry of deep-sea sediments. Some of my recent research has been concerned with deep-sea manganese nodules, and with an assessment of the environmental and scientific feasibility of subseabed disposal of high-level nuclear wastes.

I appreciate the opportunity to address the questions you have raised; questions that have concerned me for the past two decades. It is clear that we are entering a new era of marine research. The availability of oceanographic satellites will lead to our first global view of the ocean. Such a view is indispensable if we are to understand, for example, the physics of the ocean and predict its influence on climate and on man's carbon dioxide "experiment." A global view also will give us a picture of the yield of the oceanic crop of phytoplankton—the microscopic plants that support most higher forms of life in the ocean. Such a picture is one of the crucial inputs to scientifically sound fisheries management.

In my own area of research, we are beginning to decipher the way in which both the natural and artificial chemicals that enter the ocean interact with plants, animals, suspended particles, and the ocean circulation before they are buried beneath the sea floor. Such knowledge holds clues to the fate of pollutants, to the reconstruction of past climates, and to the bearing capacity of the oceans.

Our ability to meet the challenge of the next decade and beyond is open to question at the moment, however. Dr. Baker has pointed to our inadequate and decaying infrastructure. I support his conclusions. We have been living off the capital investments of the 1960's for too long. Both mission and research-oriented agencies of the federal government draw on the intellectual pool that is found in our great universities. These agencies must provide the infrastructure that keeps the pool from drying up. In the past, there has been a tendency to avoid such commitments because, for example, a single piece of equipment or a specific student fellowship is not uniquely associated with some short-term mission need. Such a perspective can only lead to disaster in the long term. The antiquity of our buildings and our research equipment, both at sea and ashore, bear witness to the sacrifice of long-term vision to short-term expediency.

What is the cure? The simplest would be the provision of block funding to oceanographic institutions to rebuild the infrastructures described by Dr. Baker and to prepare for the future. Because academic institutions have corporate memories and visions that are long, in a political context, such institutions are able to allocate resources to ensure the future health of oceanography in a rational way. The two decades after the war, when block funding provided a foundation for the oceanographic research establishment that now leads the world, provide evidence of the soundness of such a mode of funding. Unhappily, virtually every component of the federal establishment now acts as though it were able to manage long-term scientific planning better than the institutions whose future depends on such planning. This situation will be difficult to correct, but support for the infrastructure as described by Dr. Baker, and for broad, long-term research programs, such as studies of ocean climate; of chemical and biochemical reactions in the oceans, of the coastal regions where land and sea interact, of the factors that control the survival of juvenile fish and their prey, of the mid-ocean hot springs, and of the geologic processes that form the edges of the ocean basins would do much to ensure that the potential advances of the rest of the century do, in fact, become reality.

Finally, we must appreciate and take advantage of the differences between federal and university oceanographic laboratories. The federal laboratories have the ability to mount and sustain very extensive and long-term observational programs. Such programs are difficult to sustain in a university setting, yet are crucial to studies of climate and fisheries, for example. The proper preservation of good data in a readily accessible form also is a task that only an organization like NOAA can undertake. Academic institutions, on the other hand, have a continuous supply of bright young intellects, in the form of graduate students and postdoctoral researchers, who interact with experienced faculty to produce most of the new ideas about the oceans. The experiments that test these ideas rarely last more than a decade, yet form the basis for our long-term understanding, care, and exploitation of the oceans.

The complementary roles of federal and university laboratories must be recognized and maintained. If either falls into disarray, we cannot have a healthy program of marine research in this country.

Mr. STUDDS. Thank you very much, Dr. Heath.

Dr. Ross.

STATEMENT OF DR. DAVID A. ROSS, DIRECTOR, MARINE POLICY AND OCEAN MANAGEMENT PROGRAM, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Dr. ROSS. Thank you, Mr. Chairman. I appreciate the opportunity to participate in this discussion. The other speakers have focused on the many exciting marine scientific programs being proposed for the coming years. However, there will be problems in achieving these programs, including funding, facilities, the training of young scientists, et cetera, but especially important, in my opinion, will be the new Law of the Sea regime for marine scientific research.

Problems, however, sometimes can be opportunities. This, I believe, can be the case with the Law of the Sea problems for marine scientific research.

I would like to concentrate my comments on this point. My written testimony details more specific aspects.

The application of the Law of the Sea Treaty would result in approximately 42 percent of the ocean coming under coastal State jurisdiction. This has led many of the world's coastal countries, and there are over 100 of them, to focus increased and new attention on their marine and coastal environment, in particular, on their exclusive economic zones [EEZ].

However, most developing countries have little or no marine science and technology capabilities with which to undertake the necessary studies to capitalize on, even to explore, the potential of their new territories, whereas the United States has perhaps a surplus of such skills. This enclosure of the coastal ocean comes at a time when major studies such as climate, global ocean circulation, and new technological applications such as satellites, that we have heard about today, can lead to innovative ocean use. These studies and others will require access to all EEZ's, an area that, among other things, includes essentially all upwelling zones, most subduction regions, and most real or potential marine resources.

It should be stressed that EEZ's encompass that part of the ocean which often has the most variability, receives most of the erosion and waste products from land, as well as being the most used and abused part of the ocean. To exclude this region from active research would narrow our effectiveness in ocean science.

Said another way, the success of U.S. and international marine research will depend on continued access to foreign waters. This will require developing cooperative programs with scientists or institutions in these foreign countries.

A simple or single program may not be sufficient to ensure continuing access for all U.S. research vessels. Longer, more continuing relationships may often be necessary.

The Law of the Sea scenario has clearly created a challenge to oceanographers. Controls and regulations for marine science in foreign EEZ's are many and complex. Access will require detailed, sometimes written negotiations, permission, data exchange, possible training and assistance efforts. But especially required will be close cooperation with the foreign country in all phases of the research activity.

The challenge is in developing and maintaining successful and viable foreign programs without sacrificing or wasting excessive amounts of time and resources of the U.S. marine scientific community. Meeting this challenge will often require skills and infrastructure not presently available to most marine scientists.

Despite the obvious need for increased cooperative efforts in marine science with foreign countries, there exists no central point in the United States that can represent the spectrum of U.S. marine activities and interests. I feel that the United States and its marine scientists, and I include those from government, industry, and from academia, can benefit from the establishment of foreign EEZ's as well as offer assistance to these countries. The U.S. marine community has developed extensive expertise in coastal management—NOAA's Coastal Zone Management Program—in marine resource development—National Marine Fisheries, Sea Grant, industry—and in basic marine science and marine policy studies—academia.

The question, then, is are we efficiently and successfully making our skills and resources available for foreign cooperative opportunities?

The premise of my proposal is that we could and should be doing better, and to do so would lead to increased scientific research opportunities and other benefits to the U.S. marine community and, indirectly, to our Nation. This is not to criticize the several excellent cooperative programs in existence, but, rather, to suggest that there are many more opportunities and they are being missed.

The basic thrust, then, of my presentation, is to suggest the establishment of an Office for International Marine Science Cooperation that would be a focal point for foreign contacts seeking to develop cooperative programs with the U.S. marine scientific community and vice versa. The office would assist, where appropriate, in the development of such programs by involving appropriate U.S. individuals and organizations.

Some specific tasks of such an office could include, first, to serve as the contact point in the United States for foreign scientists or organizations interested in developing such programs; second, to search for opportunities within the United States and in foreign countries and to distribute this information to U.S. participants—

this aspect in itself would perhaps pay for the office. Third, to determine interest of specific U.S. marine scientists, engineers, administrators, both in government, academia, and industry, in working with foreign countries and to help match such with foreign interests; fourth, to maintain an up-to-date collection of rules and regulations of foreign countries for marine scientific research in their waters.

This latter item could be a very important task, especially if as anticipated, countries vary in their interpretation of the Law of the Sea Treaty. I anticipate that a collection of operating rules may be critical in dealing with certain countries. The materials, of course, would be made available to other institutions.

Fifth, to follow up on success of failure of foreign programs and develop a data base of key contacts, style, et cetera, of marine science activity in specific foreign countries.

In conclusion, Mr. Chairman and committee members, it is my opinion that the establishment of an Office of International Marine Science Cooperation will make U.S. marine scientists better aware of the opportunities and benefits of working in foreign waters as well as improving such opportunities. It would also allow the successful implementation of many of the programs that we have heard about today and would help gain access to foreign waters. In addition, such an office could lead to increased funding opportunities for U.S. marine scientists as well as commercial opportunities for U.S. industries.

Finally, such an action by the United States will emphasize the willingness of this country to continue as a leader in international marine activities.

Thank you for the opportunity to present this idea to you.

[Statement of Dr. Ross follows:]

STATEMENT OF DR. DAVID A. ROSS, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Mr. Chairman, Members of the Committee. My name is Dr. David A. Ross. I am a Senior Scientist in the Geology & Geophysics Department of the Woods Hole Oceanographic Institution. At this Institution I also hold the positions of Director, Marine Policy & Ocean Management Center and Coordinator, Sea Grant Program. I appreciate the opportunity to participate in this panel discussion. The other speakers will have focused on many of the exciting marine scientific programs being proposed for coming years. I will concentrate on a specific recommendation that can significantly improve U.S. oceanographic capabilities. In doing ~~so,~~ I will also comment on some foreign research programs I have been involved with and how Federal funding could be better coordinated to improve U.S. marine research possibilities.

The specific recommendation is that the U.S. establish an office to promote and develop international marine scientific cooperation. The basic premise of my comments is that the Law of the Sea Treaty, regardless of whether it is ultimately ratified or not, will bring approximately 42 per cent of the ocean under marine scientific control by various nations. U.S. marine scientists will (and already are) experiencing difficulties in working in such foreign waters. If such difficulties continue and are not ameliorated, there will be problems in implementing many of the programs you will hear about today.

I submit that the Law of the Sea Treaty and the declaration of a U.S. Exclusive Economic Zone offer the beginning of an exciting new era in oceanography. To capitalize fully on this opportunity will require the collective efforts of government, industry and academia. The benefits for such a collaboration would far exceed the modest funds needed to initiate an Office for International Marine Science Cooperation.

BACKGROUND

The past few years have seen considerable changes in how the ocean is viewed by foreign countries and this, in turn, may well influence much of the future style and direction of U.S. marine scientific research in foreign waters. The two principal factors behind these changes have been the Law of the Sea (LOS) Treaty and advances in marine science and technology, mainly by U.S. scientists and engineers. In the case of the latter, the increased knowledge and potential for ocean use, exploitation and modification could result in many economic benefits for a coastal country. This ocean "promise" has been especially attractive to developing coastal countries who see major economic potential in their new marine territories. Application of the LOS Treaty can result in approximately 42 percent of the ocean coming under coastal state jurisdiction. The combination of these two factors has led many of the world's coastal countries to focus increased or new attention on their marine and coastal environment. However, it is also apparent that most developing countries have little or no marine science and technology capabilities with which to undertake the necessary studies to capitalize on or even to explore the potential of their new territories, whereas the U.S. has perhaps a surplus of such skills. To address this issue, the Sea Grant

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International Program was proposed several years ago. It was designed to develop joint projects with foreign countries to assist them in their resource development. Subsequent budget cuts have eliminated funding for this innovative and much needed effort.

The dimension of the problems and opportunities for some coastal foreign countries can be immense. Consider, for example, Portugal which with its new EEZ (including zones for its offshore islands) is now about one part land and nineteen parts water; other countries have even more impressive ratios.

Control by coastal states over their EEZs (including jurisdiction over marine science) is a reality regardless of whether the LOS Treaty is eventually adopted or not, since most countries have already established EEZs and have or are considering legislation that covers and/or controls most ocean uses in this zone. This enclosure of the coastal ocean comes at a time when the U.S. marine science community faces a decrease in the number of ocean-going ships along with other budget constraints. However, it is also a time when major studies, such as in air-sea interactions (i.e., climate and global ocean circulation) and new technological applications such as satellites, could lead to innovative ocean use. These studies and others will require access to <u>all EEZs</u>, an area that, among other things, includes essentially all upwelling zones, most subduction regions, most real or potential marine resources and, of course, all continental margins. It should be stressed that EEZs encompass that part of the ocean which often has the most variability, receives most of the erosion and waste products from land, as well as being the most used and abused part of the ocean. To exclude this region from active research would narrow our effectiveness in ocean science studies.

It should be emphasized that many oceanic phenomena are global or regional in nature and cannot be fully understood by research in just one part of the ocean. For any U.S. scientist to propose and conduct efficient and effective studies in a foreign EEZ will require cooperation with scientists and scientific institutions from the foreign nation. This collaboration will have to be structured so as to help to define the problems, develop and implement the methods of observation, exchange information, and publish the results. Simply said, the success of U.S. international marine research will depend on continued access to foreign waters, and this will require developing cooperative programs with scientists or institutions in these foreign countries. A simple or single program may not be sufficient to ensure continuing access for all U.S. research vessels. Longer, more continuing relationships may often be necessary.

This scenario has created a challenge for oceanographers. Controls and regulations for marine science in foreign EEZs are many and complex (see attached paper by Ross and Knauss, 1982 for details). They require detailed negotiations, permission, data exchange, possible training and assistance efforts, but especially required is close cooperation with the foreign country in all phases of the research activity. The challenge is in developing and maintaining successful and viable foreign programs without sacrificing excessive amounts of time and resources of the U.S. marine scientific community. Meeting this challenge will often require skills and infrastructure not presently available to most marine scientists.

Despite the obvious need for increased cooperative efforts in marine science with foreign countries, there exists no central point in the U.S. that can represent the spectrum of U.S. marine activities and interests. Several governmental agencies have international marine affairs offices (NOAA, NSF, and the State Department, for example) and several institutions maintain active international operations. Foreign visibility is, however, generally limited, and these offices primarily serve (and correctly so) the organizations they represent. At the same time, there generally is a limited awareness between agencies, organizations and institutions of the foreign programs engaged in by others. A coastal country looking for a cooperative U.S. program within this array of organizations may find a bewildering labyrinth. From the viewpoint of the U.S. marine scientific community, a foreign program by one U.S. organization may not always lead to benefits elsewhere (such as continued access or knowledge of how to work with that country).

At Woods Hole we have had inquiries from many countries seeking assistance in what is generally called marine policy. They have immediate questions concerning coastal zone use, i.e., development and conservation of marine resources (fish, minerals, tourism, etc.). We have already developed specific programs with Colombia and Ecuador and have efforts pending with Jordan and Brazil. These four projects are quite modest and are principally funded by private foundations. With Jordan we are exploring a cooperative research program concerning the Gulf of Aqaba and its increased use. With Brazil's Interministerial Commission for Marine Resources we are developing a marine resources training program. With Colombia we analyzed several of that country's uses of its marine environment and made suggestions for future activities. With Ecuador we are assisting in developing a management plan for the Galapagos Islands, including consideration of a marine park. Although these programs have been successful in their objectives, considerably more could result, not just for Woods Hole but for the entire U.S. oceanographic community. More on this point will follow.

THE OPPORTUNITY

I feel that the U.S. and its marine scientists (from government, industry and academia) can benefit from the establishment of foreign EEZs as well as offer assistance to these coastal countries. The U.S. marine community has developed extensive expertise in coastal management (NOAA's Coastal Zone Management Program, for example), in marine resource development (National Marine Fisheries Service, Sea Grant and industry) and in basic marine science and marine policy studies (academia, in general). The question then is, are we efficiently and successfully making our skills and resources available for foreign cooperative opportunities? The premise of my proposal is that we could and should be doing better, and to do so would lead to increased scientific research opportunities and other benefits to the U.S. marine community and, indirectly, to our nation. This is not to criticize the several excellent cooperative foreign programs in existence, but rather to suggest that there are many more opportunities and they are being missed.

PROPOSAL

The basic thrust of my presentation is to suggest the establishment of an Office for International Marine Science Cooperation that will be a <u>focal point</u> for foreign contacts seeking to develop cooperative programs with the U.S. marine scientific community (and vice versa). The Office would assist (where appropriate) in the development of such programs by involving appropriate U.S. individuals and organizations. The main objectives of such an Office would be as follows:

- To improve opportunities and efficiencies for those in the U.S. marine community wishing to work with foreign countries (and in foreign waters).

- To improve access for foreign countries and institutions to marine scientific research and training opportunities with U.S. organizations.
- To collect and circulate information to the U.S. marine scientific community concerning opportunities, mechanisms and funding sources for foreign programs.
- To identify countries or areas for the U.S. marine community with particular problems or requirements, and advise on mechanisms for dealing with such problems (in particular, from scientists who have had experience in such countries).
- To identify U.S. scientists interested in working in specific fields in specific foreign countries.
- To assist in the development of multidisciplinary (and perhaps multinational) teams.

Before discussing these objectives more fully, two points should be addressed. (1) Is such a mechanism needed? (2) If so, where should it be located?

Is Such a Mechanism Needed?

The interest of other countries in studying, evaluating and exploiting their coastal and offshore potentials is obvious to those individuals involved with international activities. Two recent Ocean Policy Committee (National Academy of Science) Reports (OPC, 1981; OPC, 1982) have described this interest. U.S. marine scientists have shown continued interest in working in foreign waters regardless of LOS problems (Ross et al, 1983). In addition, there seems to be a clear, yet undocumented, increase in visits of foreign scientists and officials to U.S. marine institutions, in many instances, to explore mechanisms for cooperation.

The 1981 OPC study (conducted by its Marine Technical Assistance Group) looked at several specific points including an assessment of U.S. abilities to meet its marine assistance goals, as well as that of the developing country. The study also provided recommendations on policies and mechanisms for future U.S. programs of marine technical assistance and cooperation. A workshop held in La Jolla, California was attended by about 60 individuals including 20 representives from developing countries, international institutions, or donor countries other than the U.S. A key recommendation of the meeting was that an office be established as a central point of contact for U.S. or foreign investigators seeking information on U.S. support for marine-related projects. It was also recommended that economists and social scientists be involved in planning, management and evaluation of marine-related projects to assure adequate consideration of the sociopolitical and economic framework of the host country.

One mechanism that has been partially successful for U.S. scientific involvement with foreign countries has been the Intergovernmental Oceanographic Commission (IOC) and the Marine Division of UNESCO (see attached paper by Ross and Healey, 1983 on international marine science organizations and their role in foreign programs). However, some future U.S. opportunities may be reduced or eliminated due to U.S. withdrawal from UNESCO. Another technique for development of foreign marine scientific projects has been the previously mentioned Sea Grant International Program. This program currently has no specific budget, although a few small foreign efforts continue with private funds. Private foundations such as the William H. Donner Foundation, the Tinker Foundation and others, have funded cooperative foreign programs (at the University of Miami, Scripps Institution of Oceanography, University of

Delaware and the Woods Hole Oceanographic Institution, for example), but foundation resources are limited and often directed toward specific geographic regions and certain U.S. institutions. It should be appreciated that foreign programs can create opportunities for new research that might not be possible otherwise.

I have discussed the idea of an Office for International Marine Science Cooperation at several forums including OCEANS '83, the International Ocean Science Policy Group of the National Academy Board on Ocean Science and Policy (BOSP), the University-National Oceanographic Laboratory System (UNOLS), and the National Advisory Committee for Oceans and Atmosphere (NACOA). The general response to the concept is favorable and UNOLS is considering it further. Expectedly, however, there is a concern about funding (a projected budget of less than half a million dollars per year). Since this Office would benefit all components of U.S. marine science activities, perhaps the initiatve should come from this Committee.

Where Should the International Marine Science Cooperation Office be Located?

There are several obvious locations for such an Office, including within the federal government (State Department, National Science Foundation, or National Oceanic and Atmospheric Administration), within the academic community (a specific institution, the University National Oceanographic Laboratory System [UNOLS] or the Joint Oceanographic Institutions [JOI]), or somewhere separate from any of these entities, such as within the National Academy of Science. I visualize the first few years of this program as an experimental period and see pros and cons for any of the above locations. At any location, a key challenge will be to ensure that the Office is perceived as (and indeed is) an "honest broker" willing to consider all interests of the marine community (academia, government and industry). In order to maintain the broadest possible spectrum of contacts, the Office probably should be located outside the U.S. governmental structure where it would be neither an official agency of the U.S. government nor responsible for coordinating governmental programs (nor would it be a funding agency). Coordination, policy direction and new initiatives for cooperation within the U.S. government would remain, as before, the role of appropriate governmental bodies. The Office for International Marine Science Cooperation might become a spokesperson for marine technical cooperation but should not lobby for specific programs or requests. The Office must carefully distinguish U.S. foreign policy considerations from scientific considerations. If science is used to develop foreign policy objectives, the policy must be kept separate from the research protocol.

SPECIFIC TASKS

First, it should be emphasized that the focus of the Office is to help develop new cooperative programs with foreign countries. The Office is not intended to interfere with or supplant individual programs or activities within any part of the marine community. Specific tasks of the Office could include (a complete list would be established by an Advisory Committee):

(1) Serve as the contact point in the U.S. for foreign scientists or organizations interested in developing cooperative marine programs with U.S. organizations. This will require informing foreign governments and agencies as to the existence of the Office. U.S. agencies, institutions and universities must also be informed, not just of the existence of such an Office but also of its benefits and objectives. A good communications network must be established.

(2) Search for opportunities both within the U.S. and in foreign countries, and distribute this information to U.S. participants. This will require a good U.S. and foreign contact network that would be developed as part of Item (1).

(3) Determine interests of specific U.S. marine scientists, engineers, administrators (in government, academia and industry) in working in foreign countries, including their fields of specialization as well as geographical interests. This will involve contacting marine institutions and organizations, developing a list of interested individuals and obtaining other appropriate information. Data will be computerized and be quickly available to others via computer networks already in existence.

(4) Help match U.S. scientists and their interests with foreign requests.

(5) Maintain an up-to-date collection of rules and regulations of foreign countries for marine scientific research in their waters. This will involve obtaining data from the U.S. Department of State, other agencies and U.S. scientists. This can become an important task, especially if, as can be anticipated, countries vary in their interpretation of the LOS Treaty. I anticipate that a collection of "operating rules" may be critical in dealing with certain countries. Material will be made available on request to U.S. scientists and institutions. This information and other items could also be made available via a newsletter (electronic and/or printed).

(6) Follow up on success or failure of foreign programs and develop data base of key contacts, style, etc, of marine science activity in specific foreign countries.

CONCLUSION

In my opinion the establishment of an Office for International Marine Science Cooperation will make U.S. marine scientists better aware of the opportunities and benefits of working in foreign waters as well as improving such opportunities. It will also allow the successful implementation of many of the programs that we have heard about today. In addition, such an Office will lead to increased funding possibilities for U.S. marine scientists and commercial opportunities for U.S. industries. Finally, such action by the U.S. will emphasize the willingness of the U.S. to continue as a leader in international marine activities.

Thank you for the opportunity to present this idea to you.

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ATTACHMENT 1

How the Law of the Sea Treaty Will Affect U.S. Marine Science

David A. Ross and John A. Knauss

Negotiations concerning marine science and other issues at the third United Nations Conference on the Law of the Sea (UNCLOS III) began in 1974. On 30 April 1982 a Law of the Sea Treaty (1) was approved by a vote of 130 to 4—the United States, Venezuela, Turkey, and Israel voted against it and there were 17 abstentions. Eventually 60 nations must ratify the treaty for it to enter into force. The United States, in spite of its negative vote, can still eventually sign and later ratify the treaty, but the present Reagan Administration seems to be firmly against this option. U.S. marine scientists must understand, however, that once the treaty enters into effect, coastal states which have ratified it can, and probably will, enforce its regulations on all those who wish to do marine scientific research in their waters. The new regime for the ocean resulting from these negotiations will change markedly the way in which marine scientists and marine scientific research operate. If the treaty enters into force, the marine science articles will restrict many activities of U.S. marine scientists, as well as offer certain opportunities, whether or not this country signs or ratifies the treaty.

The history of marine science negotiations during UNCLOS III has already been discussed (2). Most countries supported restrictions on marine research. Its staunchest supporters were the United States, the Soviet Union (until 1976), West Germany, the Netherlands, and occasionally Japan (3).

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The Law of the Sea Treaty

The treaty recognizes several distinct juridical regions of ocean space including internal waters, territorial seas, straits used for international navigation, archipelagic waters, exclusive economic

Summary. The Law of the Sea treaty will clearly affect the way U.S. marine scientists operate in about 40 percent of the ocean. The matter will be made even more complex by the apparent intention of the Reagan Administration to remain outside the treaty.

zones, the continental shelf beyond 200 miles, a region called simply "the area," and the high seas. It establishes boundaries between the juridical regions (or at least defines the method by which such boundaries are to be determined), the mix of coastal state and flag state jurisdiction within each region, rules of conduct, and methods by which disputes about the interpretation of the treaty will be considered. Several jurisdictions, such as the territorial seas and the high seas, have been recognized in international law for many years (Fig. 1), but others such as the exclusive economic zone, archipelagic waters, and "the area" are completely new (4). Broadly speaking there is more restriction as you move from the open ocean toward the coast, from complete freedom on the high seas to absolute coastal state jurisdiction over foreign research in a coastal nation's internal waters.

In the treaty the term "marine scientific research" is not defined. The treaty does say that "marine scientific research shall be conducted exclusively for peaceful purposes, . . . shall be conducted with appropriate scientific methods . . . , [and] shall not unjustifiably interfere with other legitimate uses of the sea" (Article 240). Likewise, "states and competent international organizations shall promote and facilitate the development and conduct of marine scientific research in accordance with this Convention" (Article 239). In addition, coastal states "shall endeavour to adopt reasonable rules, regulations and procedures to promote and facilitate marine scientific research . . . beyond their territorial sea and to facilitate . . . access to their harbours and promote assistance for marine scientific research vessels" (Article 255). Although these articles, except 240, seem supportive, they are nonbinding.

Internal waters. Internal waters include rivers, bays, lakes, and other areas on the landward side of the base line from which the territorial sea is delineated. As in the 1958 Convention on the Territorial Sea and Contiguous Zone the coastal state exercises complete jurisdiction over who shall enter its internal waters to conduct marine scientific research and under what conditions.

Territorial sea. The treaty proposes the establishment of a territorial sea of up to 12 nautical miles from shore. Within the territorial sea the coastal state has "the exclusive right to regulate, authorize and conduct marine scientific research. . . . [which] shall be conducted only with the express consent of and under the conditions set forth by the coastal State" (Article 245). These provisions are already accepted practices under international law, set out in the 1958 Convention on the Territorial Sea and the Contiguous Zone; the new aspect is a clear definition of the 12-mile width of the territorial sea. There is no mention of the mechanisms to be used to get permission to conduct research in a country's territorial sea or the conditions that a coastal state can impose on a researching state or institution. As of May 1981, 80 states claim a 12-mile territorial sea, 25 claim more than 12 miles (14 claim 200 miles), and only 28 claim less than 12 miles (5). The treaty should eliminate claims of more than 12 miles for a territorial sea.

Although coastal states have sovereignty over the territorial sea, there is the right of innocent passage. However, Article 19 [paragraph 2(j)] eliminates "the carrying out of research or survey activities" as an accepted activity under innocent passage.

Straits used for international navigation. The definition and acceptance of a territorial sea 12 nautical miles wide will have an important effect on 116 straits (6) that are more than 6 but less than 24 miles wide, such as Bab el Mandeb and the Strait of Gibraltar; these would be included within the territorial seas of the adjacent states. Article 40 states that "foreign ships, including marine scientific research and hydrographic survey ships, may not carry out any research or survey activities without prior authorization of the States bordering straits." Thus for purposes of marine scientific research, international straits less than 24 miles wide are treated as territorial seas (Fig. 2).

Archipelagic waters. The waters around the Philippine Islands were claimed by that government in 1955, and Indonesia made a similar claim a few years later, but neither action was given wide recognition until UNCLOS III. A series of articles in the treaty will permit archipelagic states to define base lines for archipelagic waters. The actual extent of these waters is not clear, although the treaty defines the rules by which they will be determined. An archipelagic state is one formed by one or more archipelagos, such as Indonesia and the Philippines. The United States cannot claim archipelagic status for Hawaii, nor can Equador for the Galápagos Islands. An archipelagic state may draw straight base lines joining the outermost points of the outermost islands provided that the ratio of water to land of the area encompassed does not exceed nine to one. The archipelagic state exercises the same jurisdiction over marine scientific research in its archipelagic waters as it does over such research in its territorial sea.

Exclusive economic zone. The exclusive economic zone is another new concept and presents major problems for marine science. This zone extends 200 nautical miles (370 kilometers) from the baseline from which the territorial sea is measured (Fig. 1B). Consequently, it includes most of the world's coastal waters and most of the continental shelves, in a geological sense. (The treaty, however, does not seem to apply to the Antarctic continent.) Altogether, the territorial sea, archipelagic waters, and exclusive economic zone include about 32 percent of the ocean (7). The conditions for marine scientific research in a foreign country's exclusive economic zone (or on the continental shelf within the zone) are a consent regime with a strong set of requirements. There are six important conditions.

1) Consent is necessary and shall "in normal circumstances" be granted (Article 246, paragraph 3). Consent can be denied if the project (i) "is of direct significance for the exploration and exploitation of natural resources, whether living or non-living"; (ii) "involves drilling into the continental shelf, the use of explosives or the introduction of harmful substances into the marine environment"; (iii) "involves the construction, operation or use of artificial islands . . .;" or (iv) if the request of consent contains inaccurate information "or if the researching State or competent international organization has outstanding obligations to the coastal State from a prior research project" (Article 246, paragraph 5). A coastal state's decision based on these four provisions is not reviewable by a third party (Article 297, paragraph 2).

2) Specific information must be supplied not less than 6 months before the start of the project. Research states or international organizations must provide

descriptions of (i) "the nature and objectives of the project", (ii) "the method and means to be used, including name, tonnage, type and class of vessels and a description of scientific equipment"; (iii) "the precise geographical areas in which the project is to be conducted"; (iv) "the expected date of first appearance and final departure of the research vessels, or deployment of the equipment and its removal, as appropriate", (v) "the name of the sponsoring institution, its director, and the person in charge of the project"; and (vi) "the extent to which it is considered that the coastal state should be able to participate or to be represented in the project" (Article 248).

3) Specific conditions must be met. Applicants for consent to conduct research must (i) "ensure the right of the coastal state, if it so desires, to participate or be represented in the marine scientific research project, especially on board research vessels . . .;" (ii) provide preliminary and final reports, if the coastal state so requests; (iii) provide access for the coastal state to all data and samples for the project and "furnish it with data which may be copied and samples which may be divided without detriment to their scientific value"; (iv) provide, if requested, "an assessment of such data, samples and research results or provide assistance in their assessment or interpretation"; (v) ensure "that research results are made internationally available through appropriate national or international channels"; and (vi) "inform the coastal state immediately of any major change in the research programme" (Article 249).

4) "Communications concerning the marine scientific research projects shall be made through appropriate official channels unless otherwise agreed" (Article 250). These official channels will probably be foreign ministries and the U.S. Department of State. This requirement may lessen the role of scientist-to-scientist relationships that so often have been successful in developing projects. On the other hand, the provision might lessen the ambiguity concerning foreign responsibility for granting the permission, a point which has been troublesome at times.

5) Coastal states can suspend research activities (i) if they are "not being conducted in accordance with the information communicated" (that is, the information requested in Article 248), or if the conditions specified in Article 249 are not met; or (ii) if there is a major change in the research project or activities (Article 251). Coastal states may require the cessation of marine scientific research activities if such problems or changes "are not rectified within a reasonable period of time" (Article 253).

6) After permission to conduct research is granted, "land-locked and geographically disadvantaged States" may request to receive the information provided under Articles 248 and 249. These states may also participate when feasible in the project through qualified experts, although the coastal state may object to the choice of experts (Article 254).

Notwithstanding the six conditions, consent is implied, and a researching state or competent international organization could begin research 6 months after submitting its request if the coastal state has not denied consent within 4 months after receiving the information specified in Articles 248 and 249. However, it should be appreciated that the coastal state could still ask for additional information and effectively postpone a decision (Article 252).

The issue of publication of scientific results is not always clear. The treaty encourages publication and the flow of scientific data (Article 244, paragraphs 1 and 2). However, with respect to the regime of marine scientific research in the exclusive economic zone and in the continental shelf, Article 249 (paragraph 2) requires "prior agreement for making internationally available the research results of a project of direct significance for the exploration and exploitation of natural resources." Thus if a coastal state determines that the research program for which it gives permission under Article 246 (paragraph 5a) is "of direct significance for the exploration and exploitation of natural resources, whether

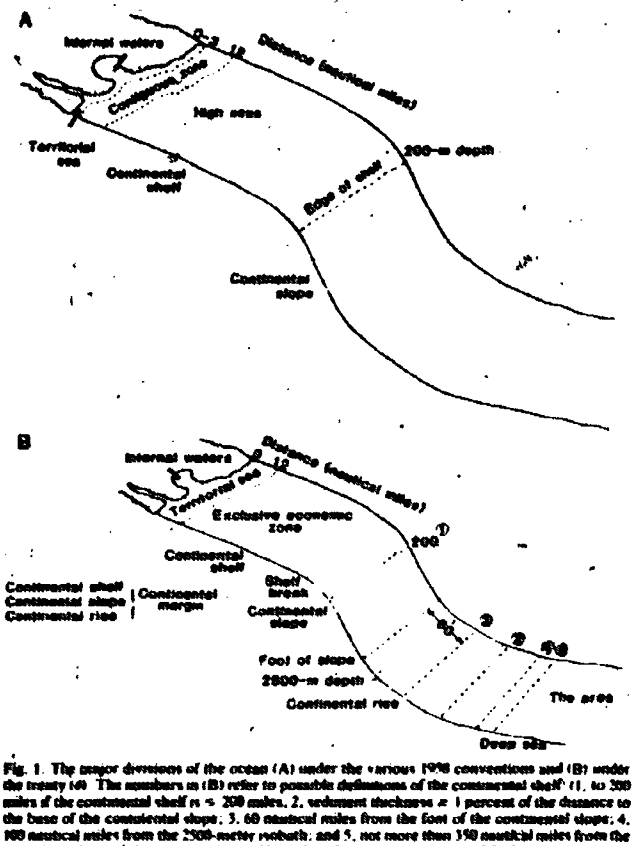

Fig. 1. The major divisions of the ocean (A) under the various 1958 conventions and (B) under the treaty (4). The numbers in (B) refer to possible definitions of the continental shelf (1, to 200 miles if the continental shelf is ≤ 200 miles, 2, sediment thickness ≥ 1 percent of the distance to the base of the continental slope; 3, 60 nautical miles from the foot of the continental slope; 4, 100 nautical miles from the 2500-meter isobath; and 5, not more than 350 nautical miles from the inner boundary of the territorial sea. Note that the relative position of 2, 3, and 4 can vary depending on the characteristics of the sea floor. (Horizontal distances are not accurately drawn.)

living or non-living," it can also control publication of such results. Presumably any restrictions on publication should be agreed upon at the time that permission is granted for the research.

Continental shelf beyond 200 miles. The continental shelf has a complex, nonscientific definition (Fig. 1B). The outer edge of the juridical continental shelf sometimes roughly corresponds to the outer edge of the geological continental margin. For all coastal states the juridical continental shelf extends at least 200 nautical miles to the edge of the exclusive economic zone. The requirements for marine scientific research on the continental shelf within the exclusive economic zone are the same as those for the latter. If the continental margin (shelf, slope, and rise in the geological sense) extends beyond 200 nautical miles, the outer edge is determined by the foot of the continental slope or the thickness of the sedimentary rocks (how this thickness is determined is not stated) (Article 76, paragraph 4); in any case, the outer edge of the shelf shall not exceed 350 nautical miles from the territorial sea base line or 100 nautical miles from the 2500-meter isobath (Article 76, paragraph 5) unless the plateau, rise, cap, bank, or spur extends beyond 350 miles (Article 76, paragraph 6). A Commission on the Limits of the Continental Shelf is to be established to help coastal states sort all this out. The exact areal extent of this region cannot be determined at this time, but some unofficial estimates put it at about 8 to 10 percent of the ocean (7). The provision concerning sediment thickness (Article 76, paragraphs 4 and 6) is bound to cause confusion and allow for excessive claims.

The same conditions described for the exclusive economic zone apply to research on the continental shelf except that a coastal state may withhold consent only in areas it has publicly designated as subject to exploitation or detailed exploratory operations within a reasonable period of time (Article 246, paragraph 6). Research in the water column above the continental shelf and beyond the limits of the exclusive economic zone is not considered research on the continental shelf. For purposes of marine scientific research this area is the high seas.

The 1958 Continental Shelf Convention states that "consent shall be obtained in respect of any research concerning the Continental Shelf and undertaken there" (Article 5). The edge of the shelf was defined under that treaty as being "outside the area of the territorial sea and [at] a depth of 200 meters or beyond that limit to where the depth of superadjacent waters admit of the exploitation of the mineral resources of the said area." At present this definition is better than the one in the treaty because few countries, if any, are exploiting beyond 200 miles or will do so in the near future. However, until a country is prepared to begin development of its continental shelf beyond 200 miles, Article 246 (paragraph 6) of the treaty, states that the coastal state cannot withhold its consent.

"The area." The seabed beyond coastal state jurisdiction (that is, beyond the continental shelf) is defined in the treaty as "the area." There are no significant restrictions in the treaty concerning marine scientific research in "the area" and "States' parties may carry out marine scientific research in the area" (Articles 87, 143, and 256). In addition, states "shall promote international cooperation in marine scientific research" (Article 143). A Deep Seabed Authority, established by the treaty, may carry out research either directly or through contract and is charged with promoting and encouraging marine research as well as disseminating scientific knowledge.

High seas. High seas freedom of scientific research is one of six "freedoms" explicitly listed for the high seas (Article 87). The high seas are that part of the ocean water column that excludes internal waters, territorial seas, archipelagic waters, and exclusive economic zones. This region covers approximately 69 percent of the 362 million square kilometers of the ocean. Freedom of research was not an explicit freedom of the seas in the 1958 Convention on the High Seas.

Dispute Settlement

Part XV and annexes V, VI, VII, and VIII of the treaty contain articles outlining in some detail how disputes arising from this convention are to be settled. With three important exceptions all disputes concerning marine scientific research are subject to compulsory dispute settlement. These exceptions are the right of the coastal state to withhold consent for marine scientific research in the exclusive economic zone and on the continental shelf beyond 200 miles and to order suspension or cessation of such research.

Thus the articles in the treaty that are most likely to generate disagreement are subject to conciliation but not to compulsory dispute settlement. Because the dispute settlement procedures are lengthy and expensive, it is also not likely that they will be used often for marine scientific research issues, and even if they are, it is doubtful that the results would be sufficiently timely to save the specific project that generated the dispute. One can hope, however, that the threat of evoking the dispute settlement clauses will minimize arbitrary or capricious actions by coastal states and that for those cases where there are honest differences of opinion the dispute settlement provisions may eventually provide some interpretive flesh to what are often ambiguously worded articles.

Implications

The restrictions imposed by coastal states on marine scientific research have been increasing rapidly since at least 1964 with the entering into force of the 1958 Convention on the Continental Shelf, and they are not likely to diminish (8), even if this treaty is not ultimately ratified. But if the treaty enters into force and is widely subscribed to, U.S. scientists wishing to work in jurisdictions claimed by other nations under the treaty will certainly be expected to comply with the treaty provisions. The provisions affecting marine scientific research clearly require changes in the way that U.S. scientists, institutions, and funding organizations operate when the proposed research is in another nation's territorial sea, exclusive economic zone, or continental shelf. A foreign country that wants to refuse or delay a project will have no trouble in finding a justification to do so, although the dispute settlement provisions may provide some limited help. On the other hand, if a country is supportive of the research effort, or at least neutral, the detailed requirements of the treaty may to a large degree become merely administrative tasks, and in some instances the detailed provisions may reduce misunderstandings.

One result of the treaty may be an increase in international programs and special bilateral arrangements. The treaty encourages development of bilateral and multilateral agreements "to create favorable conditions for the conduct of marine scientific research" (Article 243). Such agreements have already been used by the National Oceanic and Atmospheric Administration and are discussed in a recent report on the general objectives of U.S. bilateral marine science agreements (9).

Oceanographers may have to be prepared to play a more active role in organizations such as the Intergovernmental Oceanographic Commission (IOC) and the World Meteorological Organization

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(WMO). The importance of participating in international organizations stems from Article 247, which provides a mechanism by which organizations may gain consent for projects in the waters of member states. However, in the case of the IOC, this will require a more scientific focus than has been common within this organization. To develop foreign programs will require frequent meetings between U.S. and foreign scientists and administrators. Support for such meetings, before programs are in place, may require the establishment of a separate funding source that can be used to explore and discuss possibilities for foreign efforts.

All participants (scientists and administrators) interested in working in foreign waters must understand the implications of the treaty. Journal articles, meetings at individual institutions, or discussions at scientific meetings will help, but the learning process probably will be lengthy and often painful. In 1978 recommendations were proposed for a complex series of operating procedures that would be necessary for U.S. institutions and scientists to use to operate under the draft treaty at that time (10). The report covers many of the details necessary for working in the new regime and should be read by any marine scientist interested in research in foreign waters.

Although a more knowledgeable group of marine scientists is necessary, more still will be required. Funding organizations and research institutions should be aware of the new conditions on marine research and should recognize that training, data evaluation, and the like will be needed. Such activities may divert scientists from their prime objectives, but the scientists should not be penalized because of time spent on them. Oceanographic institutions, either individually or jointly, perhaps through the University National Oceanographic Laboratory System (UNOLS) or the Joint Oceanographic Institutions, Inc. (JOI) should consider establishing a "foreign office" that can help scientists, administrators, and funding agencies develop and keep track of foreign activities. It would be naive to think that most scientists will be able to wander through a maze of regulations imposed by the treaty and prepare, even many years later, an administratively, scientifically, legally, and internationally satisfactory program.

All scientists will have to see to it that their colleagues and institutions act responsibly, since coastal states can refuse to allow further research in an area if past responsibilities and obligations have not been fulfilled. Nongovernmental organizations such as UNOLS or JOI may

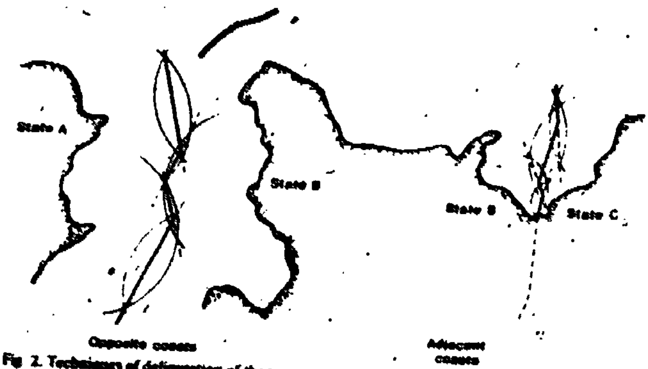

Fig. 2. Techniques of delimitation of the territorial sea between states with opposite or adjacent coasts. The situation shown for opposite coasts is that covering straits less than 24 miles wide.

be able to play a role in ensuring that individual members abide by the provisions of the treaty. The treaty puts the burden of compliance on the researching state, not the private scientist or his institution. Since a coastal state can deny a research request from a country if there are outstanding obligations against a previous project conducted by that country, how and when the obligations from a previous research project are terminated should be clearly defined in initial negotiations if possible. The threat to publication rights for research of direct significance for the exploration and exploitation of natural resources should also be considered in early stages of negotiation.

For U.S. marine science and marine scientists to be able to continue their activities in the world ocean will require additional administrative and funding considerations. For example, foreign participation in the research and the sharing of data may add costs beyond those of "just doing science." Also, the development of foreign programs will require more lead time and may impose additional costs. The necessity of having at least a 6-month lead time to get permission to conduct research has implications for the funding cycle in organizations such as the National Science Foundation and the Office of Naval Research, which tend to operate on a 1- or 2-year financial calendar.

Even when marine scientists and funding agencies exercise great care in living up to the provisions of the treaty, problems may often arise—for example, research activities can be suspended if there is a major change in a project. If coastal states interpret "major change" as a delay due to ship breakdown, or weather, or a change in plans because of loss of equipment or adjustment of a ship track in accordance with information gained during the cruise, then marine scientists will soon stop asking for permission to work these areas. For these and other reasons marine scientists may avoid working specific areas because of anticipated or past difficulties in conducting research. Perhaps this can already be seen in general avoidance of marine research in such areas under the jurisdiction of Trinidad and Tobago, the Soviet Union, and India. However, by systematic avoidance of such areas the worst fears about the treaty may be realized. Marine scientists should be prepared to test and if necessary challenge strict or arbitrary interpretations, and the U.S. government must be prepared to support their efforts.

In the Interim

As difficult as it may be to live with the provisions of the treaty, the situation during the next few years may be even more difficult, depending at least in part on the final U.S. position with respect to a treaty. There are a range of possibilities. One, albeit remote, is for the treaty not to gain the necessary 60 adherents to enter into force. In this instance, marine scientists would be faced with varying unilateral claims of coastal states. As of May 1981, 60 nations have either specifically or indirectly claimed jurisdiction over marine scientific research in their 200-mile zones (11). Because of these claims marine scientists should expect regulations in the 200-mile zones to be at least as restrictive as those in the treaty. The second possibility is for the treaty to enter into force but with the major maritime powers refusing to sign it. Under this condition it is difficult to prejudge the extent to which the provisions of the treaty, including those on marine scientific research, would eventually gain the status of "customary international law."

A third possibility is for the treaty to gain wide adherence with the United States being the only significant holdout. If this should occur, the United States has several options. It could enact national legislation embodying the essential provisions of the consent regime for the exclusive economic zone or adopt such provisions by administrative order, if such is possible. Either way, the United States would be providing tacit agreement to that part of the treaty pertaining to marine scientific research and presumably would recognize similar claims by other nations. At the other extreme, the United States could ignore the marine scientific provisions of the treaty. Then U.S. marine scientists wishing to work in foreign waters might find themselves in a Catch-22 situation since the Department of State would not process their requests as required by the treaty, and coastal states would not honor requests from the United States that did not come "through appropriate channels." In the absence of a specific bilateral arrangement, U.S. marine scientists who wanted to work in another nation's 200-mile zone would be forced either to send a research vessel into the zone without permission or to find some face-saving way for the United States to seek permission, such as asking to work in the coastal state's 3-mile territorial sea, a jurisdiction that the United States does recognize.

In any event, the legal problems facing those marine scientists who plan to work in foreign waters during the next few years may be as complex and as difficult to resolve as the scientific problems that they intend to attack. One disturbing consequence of the U.S. decision to reject the treaty is that insofar as other nations believe that a U.S. decision to reject the treaty is not in their best interests, they may be prepared to extract a price from the U.S. marine scientific community by making it increasingly difficult to work in their 200-mile zones. As outlined in this article, they have a number of ways to do so under the provisions of the Law of the Sea treaty.

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12. We thank our colleagues on the Ocean Policy Committee and its Freedom of Ocean Science Task Group for valuable discussions. In particular, we wish to acknowledge W. T. Burke, J. V. Byrne, J. P. Craven, P. M. Fye, M. H. Katsouros, E. L. Miles, R. Revelle, M. Talwani, and W. S. Wooster. This work was supported by the Pew Memorial Trust and the National Oceanic and Atmospheric Administration Office of Sea Grant under grant NA80AA-D-00077 (E/L-1). Contribution No. 5068, Woods Hole Oceanographic Institution.

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Oceanus, Vol. 25, no. 4, Winter 1982/83 ATTACHMENT 2

An Indian scientist sorts samples of plankton at the UNESCO-supported Indian Ocean Biological Center in Cochin, India. (Photo by C. Hempel — UNESCO)

International Marine Science: An Opportunity for the Future

by David A. Ross and Michael C. Healey

The style and techniques used by marine scientists to conduct research in foreign waters are clearly entering a period during which major changes will be necessary if many research activities are to continue. In the United States and other developed countries, marine scientists are experiencing decreased funding for research and a reduction in the size of academic oceanographic fleets. Furthermore, since the United States has declined adoption of the Law of the Sea Treaty, uncertainties and complexities for U.S. scientists in the international arena have increased. One technique that could counteract the curtailment of research that these events suggest and also lead to improved international opportunities in marine research is to foster new or improved mechanisms for cooperation among marine scientists, institutions, and governments.

Cooperation in marine science is not a new idea. It has been a valuable and effective technique since the beginning of the field, especially on the individual scientist-to-scientist level. Unfortunately, the individual approach will probably not be as effective in the future because of increased regulation under the Law of the Sea Treaty, especially the requirement that international communications and negotiations concerning research programs "be through official channels" (Article 250 in the treaty). Because of this requirement and other aspects of the treaty, as well as the realities of the modern world, it appears that the more institutionalized approaches to cooperation in marine science will prevail in coming years. Certainly institutionalized cooperation could reduce some of the enthusiasm and spontaneity of scientific interactions, at the same time adding to an already increasing bureaucracy in marine science. The alternative, however, could be either forestalled or lost research opportunities in foreign waters. International cooperation can take several forms and, when the politics are kept to a minimum, should be acceptable to most scientists.

The American research vessel Atlantis II, anchored at the post office in Yalta during a scientific study of the Black Sea in 1969. (WHOI photo)

Background

The Third United Nations Conference on the Law of the Sea (UNCLOS III) is entering its second decade of debate, but on April 30, 1982, a Law of the Sea Treaty was approved by a vote of 130 to 4 (the United States, Israel, Turkey, and Venezuela voted no) with 17 abstentions. There are still several hurdles the treaty must clear, including ratification by 60 countries, before it actually takes effect. Many countries, however, already have incorporated parts of the treaty into their national law. The UNCLOS III debates and the resulting treaty cover almost all aspects of ocean use and are considered to be the most complex negotiations ever undertaken. To the average observer, however, these negotiations probably seem to have focused mainly on the conflict over deep-sea mineral resources, in particular manganese nodules, which cover a major portion of the deep ocean floor and contain high concentrations of manganese, copper, cobalt, and nickel (see Oceanus, Vol. 25, No. 3).

Perhaps less obvious to the casual observer of UNCLOS III is that a large portion of the ocean will (and in several instances already has) come under coastal-nation jurisdiction. Although it is far from clear how the seaward boundaries ultimately will be drawn, at least 40 percent of the ocean will be involved — a region about equal in size to the present continental area of this planet. In addition, the remaining 60 percent of the ocean will come under an international administrative regime (the International Seabed Authority) for mineral resource development and other activities.

In the summer of 1982, the Reagan Administration announced its decision to withdraw from further UNCLOS III negotiations because of unhappiness with the treaty articles that will cover exploitation of deep-sea resources. In defense of this decision, the points are often made that deep-sea minerals are important to the United States and that American companies have already invested more than $100 million in preliminary mining operations. On the other hand, many knowledgeable individuals doubt that deep-sea mining will occur in this century, in large part because of uncertain economic conditions. Likewise, it is not clear that the United States could legally mine the deep sea if it were to remain outside the regime of the treaty.

Another group, less well publicized than the deep-sea miners, also has made large investments in the ocean and could be affected by expansion of jurisdiction and by the U.S. decision to remain outside of the treaty. We refer to the distant-water oceanographic research community: those institutions and individuals that conduct marine research in the 40 percent of the ocean that is to come under coastal-nation control.

The treaty has a section on marine scientific research that details the requirements and specific conditions for getting consent from foreign countries for work in their waters. Pros and cons of these scientific research provisions have been discussed elsewhere (Ross and Knauss, 1982). Suffice to say that there are many articles that may frustrate and delay oceanographers in the planning and conducting of research in foreign waters. The basic point is that coastal nations will control research in their internal waters, their territorial sea, a 200-mile exclusive economic zone (EEZ), and in some instances even further offshore. More than 80 countries have already established some form of control over these waters. This is an important point, since sufficient national legislation already exists to restrict the distant-water oceanographer, regardless of the ultimate fate of the treaty, and these rules, according to some, are already part of established international law.

Consequences for Oceanography

The conditions for getting permission for marine scientific research within foreign EEZs are not the subject of this article, but these conditions clearly will make the logistics of distant-water research more difficult, more costly, more time-consuming, and, therefore, less likely to occur. Successful projects will have to be developed in close cooperation with foreign countries and scientists. The procedure to develop such cooperative foreign programs often will be hard for individual scientists to ascertain and follow. Indeed it is not even clear how marine science funding organizations and the U.S. State Department will respond to the treaty's articles on marine scientific research. A potentially frustrating "Catch-22" situation can result if permission to conduct research is required from a foreign country before a project can be funded, while at the same time the State Department does not admit that coastal nations possess such authority.

There are other potentially annoying aspects of the treaty, especially since the United States has decided not to participate in future negotiations. One that should be mentioned is the question of what will happen if the State Department requests permission to conduct research within the EEZ of a country and that country responds that permission is dependent on acceptance of the marine science articles in the treaty. Acceptance of such a condition by the State Department could be interpreted as tacit acceptance of the treaty, which is contrary to the present position of the U.S. government. In this situation, the State Department would probably withdraw the request — a political decision resulting in cancellation of a scientific project that scientists in both countries may have spent several years planning and promoting. Such political niceties may be of little interest to the practicing scientist. But the question remains, how do we continue to do our important oceanographic research without being harassed or stymied by the bureaucrats of the world? One approach is to increase and improve our international cooperative oceanographic activities on the scientific as well as the diplomatic front. This approach should lead to significant benefits for the U.S. oceanographic community, but it will not be easy.

Reasons for Cooperation

There are several very good reasons for having cooperative programs with foreign countries, especially developing ones. Certainly among the most important is the altruistic motive of sharing the knowledge and benefits of research. There also are important scientific consequences of assisting foreign scientists and technicians to reach high levels of competence, in that the work these people conduct in the future will be more professional and of a higher caliber. Most scientists who participate in cooperative foreign programs find them to be very satisfying for scientific as well as personal reasons.

The treaty will create another motivation for cooperative international projects — access to foreign waters — but it will not be a straight *quid pro quo*. To develop a program will require a better understanding of a foreign country's marine scientific research needs and expectations, the latter of which are very often different from ours.

Many foreign countries, especially developing ones, look to the ocean as a source of food, energy, raw materials, and tourism rather than as a place to test scientific hypotheses. Environmental protection may not have a high priority, at least at the present time. Some coastal countries have no tradition of marine scientific research, and it is only because of their newly acquired jurisdiction over a large part of the ocean that they now look seaward. Thus, while foreign countries may be anxious to participate in cooperative marine research, their main interests will be in applied research that will focus on the assessment and exploitation of real, potential, or imagined marine resources. They also may be more interested in research on marine policy, marine economics, or coastal zone management than the more specific and traditional subdisciplines of oceanography. It has been mainly for these reasons that a number of developing countries have taken an active role in some international organizations.

Foreign countries, and their scientists, will expect to take a much more active role in the

The final planning session for the Joint Air-Sea Interaction project (JASIN), a five-year (1977 to 1983) scientific investigation involving 60 scientists from nine countries. At this meeting in Wormley, England, the group coordinated schedules for 14 ships and four aircraft that were used in a two-month expedition northwest of Scotland. (Photo by Mel Briscoe — WHOI) planning and execution of cooperative scientific programs than they have in the past. An important point in effective cooperation is that it should include individuals with compatible skills. Some of the newer countries, especially those which lack backgrounds in marine science, may have few appropriately trained people who could participate in a cooperative project. For this and other reasons, the host country may require as a condition of access that the visiting country offer practical training courses (shipboard training may be especially appealing) and assistance with developing national expertise in assessing marine resources. Most countries also will want samples of all materials collected and copies of all data and reports. None of these potential requirements is unreasonable and, if approached creatively, may actually lead to more interesting and productive projects.

Major Facilitating Organizations

Some official international organizations already exist for coordinating and promoting marine science. Unfortunately some of them have not been very successful, but it is their potential rather than their past performance that we should consider.

International organizations fall into two general categories — governmental and nongovernmental. Either can be organized on a global or regional scale. There are several global and regional oceanographic forums in which the United States participates and which are or could be effective vehicles for developing international marine activities. Among these are the Intergovernmental Oceanographic Commission (IOC), the Scientific Committee on Oceanic Research (SCOR), the International Council for the Exploration of the Sea (ICES), and United Nations organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO). In addition, there are other ways that the United States could foster marine science programs in foreign waters. These include bilateral science and technology agreements as well as trade and aid agreements that include access for marine science. Also worthwhile are specific programs like the International Decade of Ocean Exploration (IDOE) program of the 1970s, which stressed international cooperation (see Oceanus, Vol. 23, No. 1). It would be exciting to see a new effort such as this develop for the 1980s. International Sea Grant might have fulfilled this role but, unfortunately, has fallen victim to U.S. budget cuts.

Probably the first effective international governmental organization for cooperation in marine science was ICES, formed in 1902. ICES now has 18 member countries, mainly from Europe and North America (including Iceland), and essentially all have considerable expertise in marine science. ICES has focused mainly on living resources and pollution research, and sponsors important annual meetings on these subjects. Although there are national delegates to the Council, most of the scientific deliberations are handled by working committees of scientists so that recommendations of the Council are based mainly on scientific rather than political considerations. This separation of science and politics has been an important reason for the success of ICES. It should be noted, however, that ICES is an organization of developed countries having similar social and economic goals and that its members are fully supported by their governments.

Several nongovernmental international groups, with links to marine science, have developed within the International Council of Scientific Unions, including the International Association for the Physical Science of the Ocean; the International

France, Britain, and the United States are represented here as three scientists look over charts aboard the Woods Hole Oceanographic Institution (WHOI) research vessel Atlantis II in 1973. They are (left to right) Jean-Marie Auzende of the Centre National pour l'Exploitation des Océans; Michael Purdy, then a graduate student at Cambridge University and now with WHOI; and Hazar Uchupi of WHOI. As part of the Eastern Atlantic Continental Margin Project of the International Decade of Ocean Exploration (IDOE), the three were working off the coast of Morocco to study the Azores–Gibraltar plate boundary. (WHOI photo)

Union of Biological Sciences; and the International Union of Geological Sciences. These organizations are known for the scientific symposia they sponsor and for their affiliation with SCOR. This group was formed in 1957 in recognition of the interdisciplinary nature of oceanographic research and the need to bring the disparate and isolated marine disciplines together. The organization has scientific representation from 34 countries and is well known to most of the marine scientific community. SCOR is an active organization. It has working groups looking at specific problems, sponsors scientific meetings, and provides scientific advice to UNESCO. SCOR, like ICES, draws its membership mainly from developed countries.

In 1960, UNESCO sponsored an intergovernmental conference on oceanographic research that led to the formation of the Intergovernmental Oceanographic Commission, and to the recognition of SCOR as the scientific advisory group for UNESCO. IOC was created to coordinate international marine scientific programs, and one of its first activities was to take charge of the International Indian Ocean Expedition, which had been initiated by SCOR. This was ultimately a successful project that involved many countries and demonstrated the considerable potential of IOC. More recently, however, there has developed a general disenchantment with IOC. A 1982 Ocean Policy Committee study suggested that the growing ineffectiveness of IOC was a consequence of two factors. First, the general conflict between developed (North) and less developed (South) countries that has pervaded many United Nations forums including UNCLOS III also has affected scientific cooperation. Second, large-scale descriptive studies, such as that done in the Indian Ocean, for which IOC was a suitable coordinating body, are now an uncommon type of research. International projects are more localized, involve only a few countries, and could (before the treaty) be arranged on a more personal basis. Nevertheless, the IOC still has the potential to foster international cooperation. For example, projects approved by a coastal nation within an international forum such as IOC shall also be deemed to have been authorized by that country. To successfully fill such a role, however, the IOC will have to regain the scientific focus it had at its inception.

Other U.N. Agencies

There are other specialized agencies within the United Nations that emphasize cooperation in marine science and technology. These include the Ocean Economics and Technology Branch (OETB), the Food and Agriculture Organization (FAO), the International Maritime Organization (IMO), the World Meteorological Organization (WMO), the United Nations Environmental Program (UNEP), and UNESCO's Division of Marine Sciences. FAO is well known to marine scientists, as it has made many contributions to work on fishery-related problems, especially through its field programs in developing countries. OETB has focused on studies relating to ocean energy, deep-sea minerals, and marine technology transfer and application. It has

Russian scientists prepare to test an acoustic release owned by the Woods Hole Oceanographic Institution. Three Woods Hole oceanographers were aboard the Soviet research vessel for a brief cruise in 1975. A cooperative experiment was conducted, comparing Soviet and American current meters. (Photo by Robert Heinmiller — WHOI)

sponsored workshops and published technical analyses on these subjects. The IMO, previously known as the Intergovernmental Maritime Consultative Organization, concerns itself with shipping and related matters, such as pollution from ships. The WMO has been especially successful in developing international cooperation and coordinating marine meteorological projects. It could serve as a valuable model for other marine science organizations.

Chinese scientists prepare to deploy a surface buoy that will mark the location of moored instruments, as part of a recent joint research program involving oceanographers from China and the United States. (WHOI photo)

UNEP was established following the 1972 United Nations Conference on the Human Environment, where the oceans were identified as a priority area. Probably its best known activity is the Regional Seas Program. In this capacity, UNEP has acted as a catalyst for regional efforts involving governments and national institutions. Through meetings, consultations, and other activities UNEP has developed a series of action plans for 10 regional seas, such as the Mediterranean and Red Seas. The action plans attempt to assess the causes of deterioration in environmental quality of the sea and to provide scientific links with management and development of the coastal and marine environment.

UNESCO has an especially visible role in marine science activities, largely through two specific programs: the Division of Marine Sciences and the previously discussed Intergovernmental Oceanographic Commission. Both programs are especially important to developing countries. The Division of Marine Sciences has emphasized research on coastal marine systems and development of trained manpower and technical infrastructure. Efforts of the Division, as with many United Nations activities, are developed in consultation with members of the scientific community and SCOR. The Division also publishes a monograph series on oceanographic methodology, technical papers in marine science, reports on various UNESCO marine activities, and a quarterly newsletter, the *IMS Newsletter*,* which details UN efforts in the marine field. The manpower program provides fellowships, expert advisors, and small grants for travel and research, and organizes training courses, specialized curricula, and workshops. The Division's budget has been increasing relatively rapidly. It is presently $6 million, which is distributed among national programs in 17 countries and regional efforts in Asia and Africa.

In general, these UN activities are not well known to the average marine scientist. This is unfortunate, as they can offer opportunities for work in foreign waters or in the development of regional plans through an international infrastructure that is already well established. Although the research opportunities might not be the type most U.S. scientists are familiar with, they still could result in valuable scientific opportunities.

Governmental Agreements

International research cooperation can also be facilitated when governments are willing to develop specific bilateral or multilateral agreements. Bilateral agreements with countries such as Canada and Mexico, within whose waters a large portion of U.S. foreign marine research occurs (usually more than 50 percent of U.S. research clearance requests go to these two countries), or with other parts of the world, could lead to many scientific benefits for both sides. For the United States, one benefit should be improved predictability with regard to clearance and obligations in conducting research. There also can be

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Dr. N. M. Ali, left, of Egypt's Ain Shams University, looks over data with Dr. David A. Ross on a joint Egyptian-United States study of the Nile River delta in 1975. They are aboard the U.S. research vessel Chain. (WHOI photo) negative aspects, such as increased costs and time taken in negotiations and planning, compromises or additions to scientific objectives that result in extensions or modifications in the cruise track; increased costs associated with providing berthing for foreign scientists, and the broader distribution and analysis of data. One way to minimize these impacts is through active collaboration with institutions in the host countries. Some U.S. institutions already have developed cooperative relations with similar institutions in foreign countries.

These arrangements can lead to valuable cooperative research and educational opportunities, often at modest costs. In any such arrangement, however, it must be understood that permission for research in foreign waters is a prerogative of the government, and that universities and institutions may have little influence in such matters. Nevertheless, such institution-to-institution arrangements can usually provide opportunities for scientists to work on foreign research ships or in foreign institutions and may occasionally lead to more ambitious projects.

The coming years clearly are going to present a challenge to distant-water oceanographers. The legal challenge of doing marine science in foreign waters could become as complex as the scientific challenge. New and established mechanisms for cooperation could reduce the problems and frustrations while opening up new research opportunities.

David A. Ross is Director of the Marine Policy and Ocean Management Program at the Woods Hole Oceanographic Institution, where he is also Sea Grant Coordinator and a Senior Scientist in the Geology and Geophysics Department. Ross is also a member of the U.S. Delegation to the 1982 Intergovernmental Oceanographic Commission. Michael C. Healey is a Research Scientist with the Canadian Department of Fisheries and Oceans, and a Senior Policy Fellow in the Marine Policy and Ocean Management Program at Woods Hole.

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Mr. STUDDS. Thank you very much, Dr. Ross.
Finally, Dr. Schubel.

STATEMENT OF DR. J.R. SCHUBEL, DEAN AND DIRECTOR, MARINE SCIENCES RESEARCH CENTER, STATE UNIVERSITY OF NEW YORK AT STONY BROOK, NY

Dr. SCHUBEL. Thank you, Mr. Chairman and members of the subcommittee.

I am going to concentrate my comments on estuarine research.

Because of the enormous importance of estuaries to society and because of the stressed nature of many of them, it is not surprising that society has demanded that Government direct its attention to protecting and, when necessary, to rehabilitating these valuable natural resources. The responses of our elected officials at all levels to citizens' demands for action and the programs which have been generated by our Federal and State agencies responsible for protecting and managing our estuaries are laudable.

One cannot argue with their intent, but there is a problem. The programs have not worked. They have been neither effective nor efficient either in improving our scientific understanding of estuaries or in improving our ability to manage them. These two activities, the generation of new knowledge and our ability to apply it, are closely coupled.

When one examines estuarine research within the broader context of marine research, several striking differences emerge. In open ocean research, there is a healthy competition for funds among individual scientists and marine institutions throughout the country. This competition ensures a sustained high level of scientific creativity and productivity. By contrast, coastal areas, particularly estuaries, are considered to be the turf of the scientists and the institutions which reside in the States bordering each particular water body. This parochial approach to estuarine science has had very unfortunate consequences.

While the open ocean model is not entirely applicable to estuarine and near-shore studies, there are some valuable lessons to be learned. In open ocean research, most of the research that is conducted is determined in large measure by the scientists. They determine what scientific questions shall be pursued and how they will be attacked. The priorities emerge out of a well developed peer review process.

As one approaches the coastline, sociopolitical factors play an increasingly larger role in determining what science will be done. Within estuaries, these factors dominate. The pressure has been to develop applied programs, relevant programs, responsive programs, and the pressure has been intense.

It is appropriate that citizens, through the political process, should determine our objectives in using our environment, including our estuaries. These objectives dictate the kinds of management strategies needed to ensure the coexistence of multiple and conflicting uses. It follows that it is appropriate for citizens to play a leadership role in defining management objectives and goals.

What I find distressing and inappropriate is to transfer the responsibility for sophisticated scientific and technical decisions on how to obtain these objectives into the hands of concerned, well intentioned people who lack scientific and technical training needed to make sound scientific judgments.

Decisions about how we are going to use our environment are quite different from decisions about the science that we need to do to ensure these uses. Because of the lack of an appropriate foundation for our understanding of estuaries and estuarine processes, the typical management solution to a practical problem is an ad hoc attack on an unexpected problem, which sometimes results in an even larger surprise.

Because of the nature of estuarine systems, because their importance extends well beyond the States that border them, it is appropriate that the Federal Government should enter into partnerships with the States. The trouble has been, I think, to date, that the partnerships have been largely between the Federal agencies and State environmental agencies and that, for the most part, the academic research community has been excluded from these partnerships.

Academic scientists often play only minor roles in these partnerships. If they are involved at all, it is largely through response to RFP's which often are written by program managers who are not estuarine scientists, and which typically are so over-specified as to stifle creativity and innovation. Academic scientists working in estuaries find themselves competing to do science that has been developed by others. This has rather serious implications.

Of the existing mechanisms for Federal-State partnerships, and I would underline existing, to fund research in estuaries, the one which I believe has been most effective in stimulating high quality estuarine research is Sea Grant.

If Sea Grant were to be used on a larger scale for multiyear, multi-institutional, interdisciplinary studies, certainly some changes in program design and administration would be desirable. And if that were to be the case, the annual Sea Grant funeral dance would have to be eliminated.

More money for estuarine research is not the answer, not alone, at least. While more research support may well be needed and be justifiable, if it is not preceded or accompanied by fundamental structural changes in the ways in which estuarine programs are designed and conducted, I think we should expect to see only marginal improvement in our understanding of estuaries and in our ability to manage them effectively.

While more money alone is not the answer, neither are more of the same kinds of studies that we have conducted in the past. Good estuarine research, if it is going to help us manage these environments, must be programmatic. Not only must the individual pieces, the projects, be good, but they must fit into a larger, carefully conceived, scientifically sound, interdisciplinary program.

The most important estuarine studies, then, are comprehensive, multiyear, interdisciplinary studies of entire estuarine systems. Such studies fare poorly in competition for funds at the National Science Foundation. Interdisciplinary studies often fall through the cracks since there no longer is any interdisciplinary program, at least, no formal one, and regional studies are generally not looked upon with great favor.

It is interesting that while most of the academic scientists are increasingly being excluded from the estuarine realm, I think, if you examine the record, most of the publications on research from estuaries has come out of the academic community. Over a 5-year period from 1975 to 1978, 77 percent of the referred publications came out of universities who receive less than 40 percent of the support.

In conclusion, I would like to thank you, Mr. Chairman, and members of the subcommittee for this opportunity. I think there are enormously exciting research questions to be addressed in estuaries. Some of them are going to require the development of new techniques and instruments to look at estuaries in new and different ways than we have ever done before. We do have the technical and scientific competency within the scientific community to improve dramatically our understanding of estuarine systems. With better understanding, better management can follow through the application of this new knowledge. I think if we are going to make significant progress in estuarine research, we are going to have to put the scientific community back into the loop.

Thank you.

[Statement of Dr. Schubel follows:]

STATEMENT OF J.R. SCHUBEL, DEAN AND DIRECTOR, MARINE SCIENCES RESEARCH CENTER, STATE UNIVERSITY OF NEW YORK AT STONY BROOK

Mr. Chairman and Members of the Subcommittee:

I appreciate this opportunity to present to you my observations on research--basic and applied, disciplinary and interdisciplinary--in coastal and particularly in estuarine areas. In preparing these comments I spoke with a number of individual scientists from different parts of the United States whose scientific judgements I respect. I also discussed this testimony with the leadership of the Estuarine Research Federation, a confederation of estuarine research scientists on the marine coasts of the Nation. The Estuarine Research Federation includes the Atlantic Estuarine Research Society, the Gulf Estuarine Research Society, the New England Estuarine Research Society, the Pacific Estuarine Research Society and the South Eastern Estuarine Research Society. The Estuarine Research Society was organized in 1971 to promote research, to facilitate communication among members of the constituent societies, to arrange biennial conferences, and most importantly, to be a source of advice and counsel in matters concerning estuaries and the coastal zone. The Governing Board of the Estuarine Research Federation is examining ways to restructure the Estuarine Research Federation to make it even more responsive to national needs and opportunities. Because of the lack of time, I was unable to share this written statement with the officers of the Estuarine Research Federation.

As an individual, almost my entire professional life has been devoted to coastal oceanography, particularly to estuarine oceanography, and to the use of science to solve societal problems in these water bodies. I have been the Director of the State University of New York's Marine Sciences Research Center at Stony Brook since

1974. The Marine Sciences Research Center is a comprehensive coastal oceanographic center with programs in research, education and public service. We concentrate our efforts on estuaries and conduct programs throughout the World.

Before becoming the Dean and Director of the State University of New York's Marine Sciences Research Center, I spent 14 years at the Johns Hopkins University's Chesapeake Bay Institute. I have published more than 100 papers and reports on a range of subjects all of which are related to estuarine oceanography and to interdisciplinary studies. I have been the Vice President of the Estuarine Research Federation, and have served on a number of national and international advisory committees related to coastal and estuarine matters.

I shall not dwell on documenting the importance of estuarines to the Nation or on the severity of the problems they face. I believe you are well acquainted with both. Let me state only that the Nation's 850 estuaries are, in proportion to their size, the most valuable portion of our marine environment. They also are the most stressed. They serve a variety of diverse and conflicting uses which range from recreational activities and fishing at one end of the spectrum to shipping and transportation and waste disposal at the other extreme. All of these uses of the estuarine zone probably are legitimate. Few, if any, are inherently prohibitive, and most, perhaps all, need not be seriously restrictive. But the demands that the various activities make on the estuarine zone often are in conflict. The conflict arises mainly between those activities--primarily recreation and fisheries--which require the maintenance of certain levels of environmental quality and those activities for which environmental quality is relatively unimportant--activities which above some threshold do, in fact, lead to a degradation of environmental quality. I believe we will become even more dependent on our estuaries in the future. If we as a Nation are to increase substantially the amount and value of our harvests of finfish and shellfish, it will be through mariculture activities in our estuaries and coastal waters.

I shall concentrate my comments on the levels of our understanding of how estuaries operate, on what level of understanding is required for effective management, on the efficiency and effectiveness of present modes of research program development and funding (management), and on the adequacy of the support provided by the Federal government. I shall make some recommendations which I believe would lead to better science and which would permit more effective management without a substantial change in the total level of support.

I shall outline some generic research priorities, but I shall not attempt to make specific recommendations for research. That is best left to the larger research community of estuarine scientists. I have included with my testimony three recent reports which have been produced by some of the Nation's most highly regarded estuarine scientists which summarize their recommendations for estuarine research. The first, "Fundamental Research on Estuaries: The Importance of an Interdisciplinary Approach," was prepared at the request of the National Academy of Sciences. It was issued in 1983. The second, "Summary of Future Research Strategies Needed to Manage the Nation's Estuaries," was prepared with support from Sea Grant and the National Marine Fisheries Service and has just been released. I recommend these to the Subcommittee for their careful review. The third document which I have appended is regional in scope and pertains to the Chesapeake Bay. It is entitled "Ten Critical Questions for Chesapeake Bay in Research and Related Matters" and was prepared by the Chesapeake Research Consortium in 1983.

Because of the enormous importance of estuaries to society and because of the beleaguered and stressed nature of many of them, it is not surprising that society has demanded that government direct its attention to protecting and, when necessary, to rehabilitating these valuable natural resources. It also is not surprising that our attention has been directed at developing strategies to stop pollutants and pollution and to enhance aesthetic values and living resources. The responses of our elected officials at all levels to citizens' demands for action and the programs which have been generated by our Federal and State agencies responsible for protecting and managing our estuaries are laudable. One can not argue with their intent. But there is a problem. The programs have not worked. They have been neither effective nor efficient either in improving our scientific understanding of estuaries or in improving our ability to manage them. These two activities--the generations of new knowledge and our ability to apply it--are closely coupled. H.L. Mencken once observed that every question has a simple answer and it usually is wrong. He was right; at least as far as estuaries are concerned.

Estuaries probably are the most complex segments of the entire world ocean. They certainly are the most variable. Characteristic properties which change on time scales of hours in estuaries change by comparable amounts in the open ocean only over periods of years, or even decades and in some cases centuries. And spatially these same properties can change in estuaries over distances of a few meters in the vertical and a few kilometers in the horizontal where in the open ocean changes of the same magnitude occur only over distances of tens to hundreds of meters in the vertical and thousands to tens of thousands in the horizontal. There is a further complication in estuaries. In many estuaries man has compounded to a significant degree the already complex interactions of the natural processes. Human activities have modified the natural processes in estuaries in ways and degrees that are wrought in the open ocean only over geologic timespan.

When one examines estuarine research within the broader context of marine research, several striking differences emerge. In open ocean research there is a healthy competition for funds among individual scientists and marine institutions from throughout the country and indeed the world. This competition ensures a sustained high level of scientific creativity and productivity. By contrast, coastal areas, particularly estuaries, are considered to be the turf of the scientists and the institutions which reside in the States bordering each particular water body. This parochial approach to estuarine science has had unfortunate consequences.

The open ocean model is not entirely applicable to estuarine and nearshore studies, but there are some valuable lessons to be learned. In the open ocean the research that is conducted is determined in large measure by the scientific community—by the quality of their ideas and the scientific persuasion of their arguments. The scientists determine what scientific questions should be pursued and how they should be attacked. The priorities emerge out of the well-developed peer process. As one approaches the coastline, socio-political factors play an increasingly larger role in determining what scientific questions should be pursued, how they should be addressed, and whether or not specific research will be funded. Within estuaries the socio-political factors dominate. This is not surprising in view of the enormous importance of estuaries to society, the multiple and conflicting uses we make of them, the variety of political jurisdictions, and the degradation of many of our estuaries that has resulted from these conflicting demands. The pressure has been to develop applied programs, relevant programs, responsive programs--and the pressure has been intense.

It is appropriate that citizens through the political process should determine our objectives in using our environment--including estuaries. These objectives dictate the kinds of management strategies needed to ensure the coexistence of multiple and conflicting uses. It follows that it is appropriate for citizens, through citizens advisory groups and other public participation mechanisms, to play a leadership role in defining management objectives and goals. What I find distressing and inappropriate is to transfer the responsibility for sophisticated scientific and technical decisions on how to attain the objectives into the hands of concerned, well-intentioned people who lack the scientific and technical training needed to make sound scientific judgements. We have confounded social problems and scientific problems.

Public decisions about how to use our environments are quite different from decisions about what science should be conducted. Science if done properly will allow us to understand our environments and will enable us to predict how proposed uses will affect the environment. The results of these scientific investigations will allow the broader community to make choices which will have predictable and acceptable consequences. When these two roles are intertwined neither science nor society is well served. This is precisely what has happened in our dealings with estuaries. As Lewis Thomas has observed "There are some things about which it is not true to say that every man has a right to his own opinion." Too often opinions by people who lack scientific or technical expertise have determined scientific programs and technical policies for estuaries. This trend is increasing.

Because of the lack of an appropriate foundation for our understanding of estuaries and estuarine processes, the typical management solution to a practical estuarine problem is an ad hoc attack on an unexpected problem--sometimes resulting in an even larger crise.

Because of the nature of estuarine systems, because their importance extends well beyond the boundaries of the states which border them, often to the entire Nation, and because many of their most serious problems result from activities throughout their drainage basins, it is appropriate that the Federal government should enter into partnerships with the States to fund research and monitoring activities to improve our understanding of estuaries, and to fund development and implementation of management strategies to conserve and, when necessary, to rehabilitate these important natural resources.

The partnerships which have been formed between the Federal government and the states have been primarily with state environmental management agencies. These agencies often have used the funds provided to build-up large in-house staffs. On the surface, this strategy might seem desirable. It provides the states with staff committed to the problems of concern; people who do not have the distractions of graduate students and other commitments that normally go along with the responsibilities of academic scientists. But several serious problems arise in the short-term and in the longer-term from this strategy.

First, state agencies and, as a result, state staff are under enormous pressure to produce quick payoffs, to do "relevant" research on environmental problems currently in the news, and to apply the results of that research quickly--often before there is an adequate basis for its application. Governmental agencies are subject to shifting socio-political winds and environmental priorities follow. Often it is impossible for governmental scientists to stay with a problem long enough to resolve it.

Academic scientists often play only minor roles in these partnerships. If they are involved at all it often is through response to RFP's which are written by program directors who are not estuarine scientists, and which typically are so over-specified as to stifle creativity and innovation and to discourage the best scientists from applying. Academic scientists find themselves in the position of competing for funds to do estuarine research which has been developed by others, often much less qualified. The net result of the process is that academic scientists, particularly the better ones, have been alienated and many have shifted their professional allegiances away from the estuary to less political realms of the environment--either far downstream or farther upstream.

There is a further, longer-term problem. The short-term gains in responsiveness of a large in-house staff over the longer-term is transformed into a substantial loss in the states' ability to respond effectively to a changing mix of scientific and technical problems. The mix of problems changes, but the technical competencies of the civil service staffs are unable to adapt to these changes. The states develop large payrolls which must be met and they become increasingly more reluctant to divert funds to scientists outside the organizations who are equipped to attack these new problems effectively. State scientists find themselves doing research for which they are ill-equipped and the states lose the flexibility to match problems with the best problem solvers regardless of their affiliations. Both estuarine science and society are losers.

Of the existing mechanisms for Federal-state partnerships to fund research in estuaries, the one which I believe has been most effective in stimulating high quality estuarine research is Sea Grant. Sea Grant has been responsive to management, has been successful in attracting good researchers, and has been successful in translating the results of that research into forms usable by environmental managers. If the Sea Grant mechanism were to be used on a larger scale, for multi-year, multi institutional, interdisciplinary studies some changes in program design and administration would be desirable. It would require extension of intra-state Sea Grant review panels to include specialists from outside the state, and for many estuaries more active and coordinated cooperation between two or more different Sea Grant Programs would be required. And, the annual Sea Grant funeral dance would have to be eliminated. Annual threats to the continuation of this important program have been debilitating.

Because estuaries and estuarine ecosystems are particularly vulnerable to events--both natural, such as floods and hurricanes; and man-made, such as large accidental spills--special contingency funds should be established to provide rapid funding to take full advantage of the unusual scientific opportunities these "experiments" offer scientists. Documentation of the effects of events can offer valuable insights to scientists and managers into how estuaries respond to natural and anthropogenic stresses. Conventional funding mechanism can not respond on appropriate time scales for studies of events. The extensive studies of the effects of Tropical Storm Agnes (June 1972) on the Chesapeake Bay were possible because of the foresight and the courage of the Directors of the Chesapeake Bay Institute, the Chesapeake Biological Laboratory and the Virginia Institute of Marine Sciences. Studies were started within two days of peak flooding and continued for weeks before even unofficial commitments of support were secured.

More money for estuarine research is not the answer; not alone. While more research support may well be needed and justifiable, if it is not preceded or accompanied by fundamental structural (organizational) changes in the ways in which estuarine programs are designed and conducted, we should expect to see only marginal improvement in our understanding of estuaries and in our ability to manage them effectively.

While more money alone is not the answer, neither are more of the same kinds of studies which we have conducted in the past. "Good" estuarine research must be programmatic. Not only must the individual pieces--the projects--be good, but they must fit into larger carefully conceived, scientifically-sound, interdisciplinary programs. Each estuary is unique in its totality, but there are primary characteristics shared by all which permit judicious transfer of at least some of what is learned in one estuary to some or all of the others. The processes acting in all estuaries are the same, but the relative importance of those processes, their interactions and the manifestations of those interactions, vary substantially not only from one estuary to the next, but in different segments of any given estuary at any given time. In addition, there are large temporal variations in estuarine processes and in the characteristic properties produced by those processes. The programs must be designed to permit us to understand how individual estuaries systems operate. It is this level of understanding--of specific estuarine systems--that is required for the development of effective management strategies.

Many of the most important first-order disciplinary scientific questions in estuaries have been addressed; few of the second-order disciplinary questions have been considered; and almost none of the most important, complex interdisciplinary questions that relate to the interactions of the physical, chemical, biological and geological processes have been studied. It is this level of understanding which is required for effective management. The most important estuarine questions--at least for management--are fundamentally interdisciplinary in character.

This level of understanding which effective management requires also is the level which discourages support from organizations such as NSF which support fundamental research. The next generation of scientific questions will be enormously more difficult than the first.

but it is on the first where most scientists make their reputations.

The second order questions are complex and are not amenable to facile solutions or to attack by large, short-term (3-5 year) efforts. Basic research on complex estuarine interactions is still inadequate to provide an adequate scientific basis for effective management of estuarine systems including those that relate to pollution management and estuarine rehabilitation.

To manage estuaries effectively we need predictive models--models which are both process-oriented (causal) and empirically based. On balance, our modelling efforts to date have been useful, but they may well have outrun our understanding of the processes upon which they are based. Many unwary citizens and environmental managers are prone to place blind faith in the output of computers and models. I would remind you of T.H. Huxley's admonition in 1869 to the Geological Society of London regarding premature extrapolations from mathematical treatment to biological problems. "This seems to be one of the many cases in which the admitted accuracy of mathematical processes is allowed to throw a wholly inadmissible appearance of authority over the results obtained by them...As the grandest mill in the world will not extract wheat flour from peascods, so pages of formulas will not get a definite result out of loose data."

The most important estuarine studies, then, are comprehensive, multi-year interdisciplinary studies of entire estuarine systems. Such studies fare poorly in competition for funds at the National Science Foundation. Interdisciplinary studies often "fall through the cracks" at NSF since there is no longer any interdisciplinary program. And regional studies are frowned upon.

Continental shelf studies are in an explosive stage of development. While present funding is insufficient to support all of the excellent studies being proposed, the science is sufficiently exciting that it is attracting increasingly the attention of many excellent marine scientists as well as drawing people from other disciplines, such as applied mathematics. The situation in estuaries is the reverse. Some of the best scientists who worked formerly in estuaries are directing their attention farther seaward where projects are judged on their scientific merits and not on their political desirability.

Most of the contributions to the refereed literature on estuaries have been produced by academic scientists. While this is only one measure of scientific productivity, and an imperfect one at that, it does provide some useful information. Officer et al. (1981) analyzed the institutional affiliations of senior authors of refereed papers and the identifiable Federal funding of estuarine research. They reported that over a 5-year period, 1975-1980 the academic community produced 77 percent of the refereed publications, followed by Federal laboratories (15 percent) and state, municipal, industrial and other sources (8 percent). An analysis of Federal funding related to ocean pollution research, development, and monitoring showed that the projects in fiscal year 1978 were funded at a total of $164 million, of which $131 million was ascribed to research, including $40.6 million related to estuaries (Interagency Committee on Ocean Pollution Research, Development, and Monitoring 1981). Of that total of $40.6 million for estuarine research, the academic community was granted $14 million or 37 percent of the total Federal estuarine research funds. I suspect this percentage has declined since that time. Even if it has not, there has been a definite shift away from basic to what is, euphemistically called "applied" or "goal-oriented" research. I would remind the Subcommittee of something Louis Pasteur pointed out

> "To him who devotes his life to science, nothing can give more happiness than increasing the number of discoveries. But his cup of joy is full when the results of his studies find practical application. <u>There are not two sciences. There is only one science and the application of science, and these two activities are linked as the fruit is to the tree.</u>"

I would like to make a few comments about monitoring programs in estuaries and a project we are doing at the Marine Sciences Research Center which I believe could contribute to improved estuarine management.

As a Nation, we invest tens of millions of dollars a year monitoring the marine environment. Estuaries are among our favorite target areas. Relatively few of the data collected are ever analyzed and rarely are these data used in decision making. The establishment of diagnostic monitoring programs to establish the status and trends in estuarine quality must emerge from research which provides the basis for station selection, sampling frequency and the properties to be measured. Seldom does this occur. Monitoring programs which are appropriately designed and executed can provide valuable information about the estuarine environment. Many existing programs do not meet these criteria and are of little value. Monitoring programs should be scientifically and technically sound. They also should be modest in extent so that the likelihood of continuing the programs over extended periods (decades) is high. At least as much support should be provided to analyze the data as was provided to collect them.

The management of our estuarine resources is adversely affected by the difficulty of using available scientific data and information in the decision making process. The decision maker who has to make a choice tomorrow is not aided by a roomful of reports, computer printouts and journal articles that contain data and information relevant to the decision. To provide a better interface between scientific knowledge and environmental management, the Marine Sciences Research Center under the leadership of Professor Peter K. Weyl has developed personal computer-based information systems for the Port of New York and New Jersey and for the Port of New Orleans and its connections with the Gulf of Mexico.

By making use of the latest developments in microcomputer hardware and software, we have developed flexible, decentralized and inexpensive information systems that can be used independently by a variety of Federal, state and local public agencies, as well as by the private sector. The systems permit ready, interactive access to a wide variety of space-specific and generic information about the local estuarine environment.

A modification of the Port of New York and New Jersey system is currently under development, to improve the processing of permits by public agencies. A clerk enters the location of the proposed project. The system then searches a variety of information files to produce a printout that identifies and describes all potential local conflicts and environmental conditions that should be considered by the officer responsible for evaluating the permit. In addition, the printout identifies relevant maps, political jurisdictions for the site and other information. The system does not make decisions, rather it enables the officer responsible to make effective decisions more efficiently.

I would be remiss if I did not take this opportunity to make a few observations about some of the special problems and needs of our region and my own institution. We have, living within a radius of 50 miles of the center of New York City, nearly 10% of the entire population of the United States. Everyone of these individuals lives within the drainage basin of one of the estuaries in this region. On Long Island alone we have a population of more than 7 million people; everyone of whom lives within 10 miles of a coastal marine environment. If Long Island were a state, it would be the 10th most populous state in the country. If it were a nation, it would be more populous than 50% of the nations in the world today.

Long Island is coastal--in its entirety. Since we have 10% of the country's population living within the drainage basins of the estuaries of this region, one might expect that they have been the focus of intensive research. They have not. I would venture a guess that less Federal money has been spent on research in Long Island Sound, Great South Bay and the Hudson-Raritan estuarine system combined in the last century as has been spent on research in Chesapeake Bay in the last decade*. The amount of state support for basic research in the

*A large amount of Federal money has been spent on research in the New York Bight. A planned NOAA follow-up study of the Hudson-Raritan Estuarine System was significantly underfunded and was terminated before accomplishing any significant results.

estuaries of this region also has been meager. Because so little research has been done in our local estuaries, often we are unable to make sound scientific judgements and to estimate with acceptable levels of confidence the consequences of proposed alterations to the natural systems.

The most recent in a string of such incidents relates to the proposed Westway project. It comes down to a question of just how important the inter-pier areas that would be filled in are as habitat for young-of-the-year striped bass, and as a result to the striped bass population of the Hudson-Raritan estuarine system. Opinions differ widely. There are in New York a total of two academic marine and estuarine finfish biologists—two in a state whose recreational fisheries rank second only to Florida. The situation in shellfish biology is little better. To correct this deficiency we have requested funds from the New York State Legislature to initiate within the Marine Sciences Research Center a new Living Marine Resources Institute.

New York's, New Jersey's and Connecticut's estuaries and nearshore environments offer unusual opportunities for research. On Long Island there is a greater diversity of coastal environments in a limited geographical area than anywhere in the country. And, the gradient in environmental quality is extreme. At Long Island's western end—New York Harbor and the New York Bight—we have two of the most highly stressed environments in the nation. At its eastern end—the Peconics-Flanders Bay system—we have one of the most pristine estuaries in the nation. These are separated by a distance of less than 75 miles and share most of the same distinguishing natural characteristics. Only the effects of man differ markedly. This is an enormous opportunity for comparative studies. It is not a substitute for the kinds of system studies I described earlier, but rather an important opportunity to augment those studies and to produce generic knowledge which has high transfer value.

Long Island Sound is an important estuary. It is stressed at its western end by inputs of municipal wastes from New York City and because the estuarine circulation concentrates particles, and particle-associated contaminants in that part of the Sound. Most of the Central and Eastern Sound appear to be healthy and productive. Why doesn't Long Island Sound exhibit the same signs of stress as Chesapeake Bay. We do not know. It might be a good idea to spend a modest amount of money now on fundamental research to learn how Long Island Sound operates. It could save an enormous amount of money later in trying to correct problems we don't understand and did not anticipate.

There is a pressing need in the Nation for one, or more, coastal and estuarine oceanographic institutions which enjoy the same stature as out most distinguished deep sea institutions and which, like them, are viewed as national resources.

Our goal is to establish the Marine Sciences Research Center as such an international resource for studies of estuarine problems; an institution that will provide a forum which will attract scholars from around the world to focus their attention on estuaries. This is an ambitious goal, but an appropriate one considering our location and the fact that we are the oceanographic center for the largest university system in the world. It also is an attainable one. In a recent (1983) review, two of the Nation's most distinguished oceanographers pointed out."The Marine Sciences Research Center is rapidly acquiring international stature as one of the very best coastal oceanography centers in the world. Its location is excellent. The variety of adjacent coastal domains, proximity to a major urban influence, and economic importance of marine resources of the waters in the vicinity of Long Island are uniquely extreme for any comparable stretch of coastline in this country."*

Mr. Chairman and Members of the Subcommittee, I want to thank you for this opportunity to present some of my thoughts about estuarine research and management in the United States. There are enormously exciting research questions to be addressed in estuaries. Some will require the development of new techniques and instruments to look at estuaries in new and different ways than we have ever done before. We have the technical and scientific competency within the scientific community to improve dramatically our understanding of estuarine systems. With better understanding, better management can follow through the application of this new knowledge. If we are to make significant progress, we must put the science and scientists back in their proper places in estuarine science. This is particularly true of academic scientists.

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*Dr. James J. McCarthy, Agassiz Professor and Director of Harvard's Museum of Comparative Zoology and Dr. Robert O. Reid, Professor and Chairman of the Department of Oceanography of Texas A&M University.

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Summary of Future Research Strategies Needed to Manage the Nation's Estuaries

Research Strategies for the Future

The objective for this symposium was to develop research strategies for managing the nation's estuaries. The objective was approached by assembling a cadre of the nation's best estuarine researchers and challenging them to think about future research directions. Outstanding responses to these challenges where provided by researchers representing various sections of the United States coastal area and active participation by an audience representing a broad spectrum of interest. This mixture provided an excellent forum for sorting out the future directions of estuarine research.

The purpose of this final chapter is to summarize the essential points made during the symposium. Although it is understood that multi-disciplinary and interrelated approaches are necessary for progress, we organized the symposium into five critical areas so that we could focus on the issues. Those five areas are:

(1) Water Management and its Relationship to Estuarine Productivity;
(2) Sediment Management and Estuarine Productivity;
(3) Nutrient Inputs and Control of Primary Productivity;
(4) Coupling of Primary and Secondary Production; and
(5) Habitat Requirements for Fisheries Production.

It is understood that the resource called estuary includes those downstream, flooded valleys along the oceanic and Great Lakes shores of the United States.

It is important to emphasize that we must develop a means of objective evaluation of ecological risks in order to improve management perception of scientific findings. After all, the scheme of management is to be able to reduce the number of risks that something bad will happen as a result of management imprecision. Therefore, one priority research area involves the interactions of mathematicians and other scientific disciplines in multi-disciplinary efforts to improve our analysis of risk based on the best scientific information about how an ecosystem works. As our keynote address concluded, we must translate our doubts and uncertainties into the language of risk and to educate the public and policy makers about the way it should be used in making decisions.

Water management and estuarine productivity

One of the important problems facing our nation today is the allocation of freshwater resources. As the demands for water increase for municipal, commercial, industrial, agricultural and recreational needs the downstream availability of that water decreases. Estuaries lie at the downstream end of freshwater resources. As land use activities change both around the estuary and near the upstream tributaries the quantity, quality and timing of freshwater inflows to the estuaries will also change. Since, by definition, estuaries are intimately related to the inflow and mixture of fresh water with salt water these changes have the potential of imposing significant changes upon estuarine productivity.

The primary questions for research in this area is the coupling between freshwater inflows and primary and/or secondary production in estuaries. We need to know the quantitative relationship between freshwater inflows and the fisheries landings from individual estuaries and regional groups of estuaries. The entire spectrum, from when is there too much to too little on a seasonal and annual basis, needs to be determined.

Our problems range from not enough freshwater in some parts of the country to too much in others and our crude estimates based on current scientific knowledge are not good enough to equate the demands of estuaries to the demands of other water users. We have found that merely providing an allocation of water to estuaries based upon a mean, historical schedule has not provided the maintenance of historical productivity. The common denominator regarding water management for maintaining estuarine productivity lies in the management of watershed activities.

Sediment management and estuarine productivity

Sedimentary charácterisites are basic to the fundamental character of estuaries themselves. Sediments deposited within the rapidly changing sequence of coastal environments during the recent geologic periods are varied and complex and are fundamental to the basic characteristics of present day estuaries. The two basic aspects relating to estuarine productivity are the amount of sediments that enters the estuary and the quality of those sediments. These processes are immensely affected by the activities of man on the watershed of the estuaries. Another aspect of this problem is the long time periods (decades to centuries) involved in the movement of sediments from their sources well up in the drainage basins of major rivers down into the estuaries. While the sources of sediments are external, internal and marginal, the sources most influenced by man are external sediments along the rivers that carry them to the estuaries.

A great difficulty in research in this area stems from the fact that critical experiments necessary to elucidate relationships between ecosystems and major changes in their environment simply can not be performed. It is not feasible to manipulate tidal flushing, flooding, large scale additions or removals of substrates and also maintain a control system for comparison. Therefore, much of our research in this area have been before and after studies of major events. A major need in sediment management is the development of dredging and dredge material management plans and characterization of the [illegible]rt of sediments from external sources. One of the primary research needs is a [illegible]terization of the processes that control the movement, absorption and desorption of contaminants, rates of accumulation and transformations of sediment composition between points of entry and sites of accumulation. We need to develop an experimental procedure to relate these parameters to the response of estuarine ecosystems. We need to develop a capability to predict, for a range of environmental conditions, the agglomeration of fine grain particles within the water column and on the estuary floor and how changes in the degree of the agglomeration affects settling velocity, critical erosion velocity and the availability of particle-associated contaminents. This research in combination with good ecological studies to determine the relationship between sediments and habitat type will enable us to provide the scientific basis for controlling or mitigating sedimentation and management of the quality and quantity of stream flows.

Nutrients and other contaminants and estuarine productivity

For a long time it has been a common belief that the higher productivity of coastal waters was supported by nutrient inputs from the land. Recent research has emphasized the importance of nutrient cycling rather than inputs. There is, at present, a general excitement over the rapid rates of regeneration that are being found. It is undoubtedly true that large nutrient inputs from the land are real and rapid internal recycling occurs, there are still yet undefined many relationships between nutrient inputs, recycling and production. While analytical techniques necessary to measure nutrients have been available for several decades it has only been recently that spatial and temporal variations and seasonal cycles of nutrients have been measured in a significant sample of estuaries. It should, therefore, be emphasized that the fundamental processes underlying the relationship of nutrient flows and coastal productivity are not yet understood.

Several fundamental observations indicate that nutrient problems in estuaries are increasing. Most of the human population of the United States is concentrated around the estuaries and Great Lakes (e.g., by 1990, 75% of the population of this country is expected to live within 50 miles of the Ocean or Great Lakes). The exponential increase in the use of inorganic fertilizers of the United States has been occurring for almost a century now. Large scale conversion of wetlands to urban and agricultural developments eliminates them from their services of nutrient and sediment sinks. As a result of all these, we might expect that the amounts of nutrients have increased markedly in our estuaries. The lack of adequate long term data makes it difficult to determine if this is true.

Our knowledge of the effects of nutrient enrichment of estuarine ecosystem is primarily based on short term laboratory studies of algal cultures and short term synthesis experiments involving nutrient additions to plankton communities. These experiments have led to the conclusion that recycling is a dominant factor in the control of primary production of coastal ecosystems. However, the advent of massive debilitating algal blooms in many of the upper regions of our nation's estuaries indicate that increasing nutrient inputs from stream sources are major contributing factors. A major research need, therefore, are fundamental ecosystem level experiments to test how the estuarine ecosystem responds to a combination of nutrient inputs and recycling. Experiments involving large mesocosm tanks and field manipulations such as have been used in limology and terrestrial ecology have the potential of yielding integrated results useful for management. This will require large long term multi-disciplinary studies of ecosystem response to nutrient additions and recycling.

Though nutrient loading certainly is an important aspect of the impact on estuaries, the host of synthetic organic chemicals and metals found in estuaries pose a serious scientific question. With the plethora of synthetic chemicals currently in commerical use in this country and the rapid rate at which new ones are being synthesized raises considerable question about their impact on downstream estuaries.

These facts raise a tremendous challenge to the scientific community to develop a research protocol to understand long term, integrated responses of estuarine ecosystems to exotic materials.

Coupling of primary and secondary productivity

It has been recognized that estuarine ecosystems are characterized by intrinsically high levels of primary production. Accompanying these well documented estimates of estuarine primary productivity are apparently high levels of secondary production. Although estimates of secondary production are generally qualitative, the high yields of fishes and other organisms from estuarine ecosystems offers compelling evidence. The fundamental question, therefore, is what is the connection between high primary production on the one hand and high secondary production on the other.

While there is clearly a theoretical relationship between primary and secondary productivity, documentation of the actual pathways and satisfactory clarification of the relative importance and ecological efficiencies of individual pathways remains unresolved.

A fundamental management question revolves around the issue of whether one can protect or enhance secondary production by managing for a certain level of primary production. For example, what is an acre of salt marsh primary productivity worth in fisheries production in the receiving estuary?

The most important research need in this area involves the development of a quantitative relationship between primary production and secondary production in estuaries. This will require multi-disciplinary approaches at ecosystem level studies to unravel the myriad of food chains and relationships that exists in these coastal ecosystems. We need to know the comparative trophic importance of vascular plants vs. plankton organic matter. Related to this question is the degree to which coastal fisheries organisms utilize detritus as an energy source and the impact of removing large tracts of detritus-producing salt marshes and seagrass beds.

Food chains in estuarine ecosystems, like in other ecosystems, are interconnected both quantitatively and qualitatively. While it is obvious that quantity of biomass at one producer level helps determine the quantity of biomass at the next level, the quality may be the most significant limiting factor. For example, the production of large biomasses of blue-green algae in some of our nation's estuaries might result in very short food chain circuits because none of the secondary consumers are able to utilize the poor quality blue-green algae. Establishment of the qualitative relationships, as well as the quantitative dependency, is necessary before estuarine management can improve and this will require a rather sophisticated research effort. Traditional feeding experiments need to be improved to the extent that chemical utilization is also measured.

Habitat requirements for fisheries production

One of the traditional values of estuaries throughout the world is their role as a nursery area for many of the commercially and recreationally important species of fish. It has been well documented, however, that more fish are produced in some estuaries than in others. Well over 90% of the fish tonnage taken along the coastal fringe of the United States are dependent upon estuaries during some portion of their life cycle. This seemingly obligatory dependence has long been held to be the most important fundamental societal value placed on estuaries. Perhaps the key to more effective fisheries management is the understanding of the role that estuarine habitat plays in the production of the fisheries in question.

There are three major reasons that have traditionally been held to be the reasons why fish use estuaries. The tremendous primary production attributed to estuaries leads to an increased food availability. The often shallow and brackish to sometimes fresh water available in the estuaries offers protection from preditors on the young of many species. Certain, fundamentally important, chemicals such as vitamins and growth stimulators seem to be available in the estuaries as well as the availability of suitable physical substrates.

In recent years it has become increasingly apparent that the distinctive attributes of nursery areas are difficult to define. An important research question, therefore, is how specific is the selection for a nursery habitat and what basic criteria are needed to protect those characteristics to provide suitable fisheries production? The distribution of fisheries species in estuaries is life-stage dependent and many species use different habitats in a predictable sequence. Except for a very few species (salmon, for example), we do not know the cueing mechanisms used to initiate and guide these movements; nor do we know the relative importance of each segment in the sequence. We still need answers to basic questions of sizes and reasons for species migration, required times of residence in each segement of the estuary, and the effects of environmental variations on survival, growth and movement.

The most important fundamental question, in terms of effective mangement programs, revolves around the central question of the relationship between fish production in the estuary and the quality and quantity of nursery areas in terms of the availability of food and subsequent growth and mortality. In other words if we improve and enlarge nursery habitat in the nation's estuaries will we also improve an enlarge the fisheries production along our coastal fringe?

While there is considerable evidence that ecosystem configuration is important to fisheries production, we are far from understanding the complex mix of physiographic features which make these estuaries so productive for fish. An important integrator of estuarine habitat and coastal fisheries production are the hydrographic regimes characteristic of estuaries. In order to understand estuarine nursery utilization, it is critical that we also understand the physical characteristics of the estuaries and how these relate to the use of the nurseries by fisheries species.

The solution to all these important questions will require large, multi-disciplinary studies based on good, testable hypotheses.

[EDITOR'S NOTE.—The following documents were submitted along with Dr. Schubel's written testimony and were retained in subcommittee files: "Ten Critical Questions for Chesapeake Bay in Research and Related Matters," The Chesapeake Research Consortium, October 1983; "An Ocean Climate Research Strategy," by Ferris Webster, National Academy Press, 1984; and "Fundamental Research on Estuaries: The Importance of an Interdisciplinary Approach," National Academy Press, 1983.]

Mr. STUDDS. Thank you very much, Dr. Schubel.

I am going to begin the questioning. I have questions here that I am confident will go beyond 5 minutes. I am going to ask the staff to gently inform me when it is 5 minutes so that we can keep a fair apportionment of time for the members who are here.

Dr. Baker, you say on the second page of your statement that our research fleet will need replacement in a few years. Are you referring there to NOAA's research fleet, to the UNOLS fleet, to neither or to both?

Dr. BAKER. I am referring there to the academic research fleet.

Mr. STUDDS. Can you be more precise about the need for and the scope of the replacement required, and would you expect funding for these replacements to come from the Federal Government?

Dr. BAKER. Yes, I think in general we would be expecting funding to come from the Federal Government. A detailed study on the need for replacement of the academic fleet is being put together by UNOLS now, and that can be made available to the subcommittee.

It is important to note that the University of California has provided the Scripps Institution of Oceanography with a research vessel built with State funds, and that the University of Texas is planning to build a research vessel with State funds. These are examples of academic research vessels that will not come from Federal funding.

Mr. STUDDS. I am not sure there is a great danger of a great many additional States doing that.

Dr. BAKER. I think that is probably right.

Mr. STUDDS. Dr. Heath, you propose what you call block funding for oceanographic institutions to rebuild their infrastructure for marine scientific research. Do you have any idea of the amount of money that would be needed to do the job, and does it matter which Federal agency provides the funding?

Dr. HEATH. Accurate estimates don't really exist, I believe. The problem has barely begun to be defined, but certainly numbers will be in the $30 million per year range——

Mr. STUDDS. $30 million?

Dr. HEATH. Yes. This would be a good opening number.

As far as the appropriate Federal agency to be involved, providing that the guidelines were appropriate, I don't think it necessarily makes a lot of difference. The major block funding in the past was through the Office of Naval Research. Subsequently, of course, the National Science Foundation has played the dominant role in funding for oceanography, but I don't think there is any particular magic in either or in other organizations that make them uniquely qualified to do this.

Mr. STUDDS. What criteria should be applied to determine the eligibility of an institution for this kind of funding?

Dr. HEATH. Definitely peer review. Assessment of sensible long-range plans by peer review would maintain the kind of quality that we are used to seeing and would make sure that the funds are well-spent on high priority items.

Mr. STUDDS. What arguments would you use to convince OMB that such funding would be in the national interest?

Dr. HEATH. Well, I hope that they would look at the historical record and observe what happened to the nature and the quality and the number of scientific results which emerged during the days of block funding versus the same level of output now when the funds are cut into minute blocks. I think that they would find that in terms of efficiency, that is, the amount of product per dollar, oceanographic research was much better off with the block funding.

Mr. STUDDS. Also for you, sir, or I guess for anyone else who would like to comment, you say, Dr. Heath, on page 3 of your statement, "virtually every component of the Federal establishment now acts as though it were able to manage long-term scientific planning better than the institutions whose futures depend on such planning."

Could you elaborate a bit on that?

Dr. HEATH. I think this has largely grown up from some very valid concerns over accountability, but I think it has reached the point now where, in many cases, program managers are forced by legislation to make decisions on the allocation of funds and the way that they are accounted for which really have nothing to do with the nature of the scientific problems that are being addressed. I think that the kinds of regulations that are applied have very little to do with whether or not those funds are achieving the scientific purposes for which they were allocated.

Mr. STUDDS. Again, bear in mind that anyone is free to answer. Which agencies are doing what kind of planning that could better be done by the oceanographic institutions?

Dr. HEATH. I think virtually all of them. I think that Dr. Schubel's comments a moment ago provided an excellent example. We are faced with a number of severe difficulties in estuarine settings. It is quite clear that if one were to back off, make some rational long-term scientific plans, and allocate the resources for relatively extended periods of time, we would make much greater progress in solving those problems then we are able to do under the present regime.

Mr. STUDDS. One more on that subject, and, again, for anyone, are you confident that the institutions are better able than the Government to agree upon a coherent research plan, or is there not an analogous risk that they would be hindered by disagreements among the institutions themselves?

Dr. HEATH. Oh, I am sure there would be disagreements among the institutions, but I think that the application for peer review plus the fact that the survival of the institutions, in the long haul, depends on their effective administration of this kind of support would ensure quality. The management of these funds by somebody at the Federal level carries much less penalty to the people doing the management than would management at the institutional level.

Mr. STUDDS. Would anyone else care to respond to that?

[No response.]

Mr. STUDDS. If not, I will turn to Mr. Pritchard.

Mr. PRITCHARD. Thank you, Mr. Chairman.

I would ask generally of all the panel, are we talking about a massive influx of Federal money? Do we have to double our effort or quadruple our efforts? What are we talking about here?

Do you want to start, Dr. Baker?

Dr. BAKER. I think it depends upon what we are talking about. The National Science Foundation has put together a long-range plan for ocean sciences, based on the best scientific estimates of what they think they can do and what the community is prepared to handle. They see a logical argument for a budget, not necessarily one that would be accepted, but a logical argument for a budget that would triple the amount of funds which they currently have for oceanography research.

The NSF Division of Ocean Sciences has about $130 million and they are talking about going up above $300 million.

If we look toward satellite programs that are aimed toward oceanography, the kind of satellite program that the oceanographers would like to see operating during the next decade, that is, the decade of the 1990's, is a four-mission program that would be on the order of three-quarters of a billion dollars over a 10-year period. That is to be compared with the kind of operation we have now. The ocean drilling program, for example, is a program that costs, over a 10-year period, about $300 million. That is also a typical cost of a single satellite mission for oceanography.

So, we are not talking about a major change in order of magnitude, but we are talking about double or triple the amount of money that we currently have.

Mr. PRITCHARD. Do any of you other gentlemen want to comment? Dr. Ross?

Dr. ROSS. Not talking specifically about money; but one of the problems the scientific community faces is the general predictability of funding. In the last few years, there have been many fluctuations in the budget process and this causes an inability to make long-term plans. We have heard about Sea Grant, for one example, but there are other agencies or programs that have started up and quickly disappeared. It is difficult to work from year to year without knowing whether the program will survive; that type of behavior, regardless of the funds involved, makes it very hard to develop long-term scientific programs and to focus on the right questions and to attract bright young, scientists to participate in these endeavors.

Mr. PRITCHARD. So, besides the level, the assurance that funds will be there for a certain period of time so that people can plan their careers is vital.

Dr. ROSS. Yes, sir.

Dr. HEATH. I would support that comment, and I think one can get some insight by looking at the way that other countries deal with their scientific support for oceanography. A very typical level of commitment is 5 years although appropriations may well be on a year-to-year basis. Such a long commitment is quite unusual in academic oceanography in this country.

Dr. SCHUBEL. I certainly would add that that kind of predictability in funding is necessary in estuaries and coastal waters. We have not had that.

Dr. BOESCH. With regard to environmental quality research since most of the emphasis is placed on coastal and estuarine waters, as Dr. Schubel mentioned, very little of it is going to the long-term research of trying to understand how the systems operate. Now, we have a great diversity of coastal environments around our country, and not all of them need to be exhaustively studied. One can extrapolate from one to the other to a certain extent, but this is an area that is essentially grossly underfunded at present and it is going to be expensive simply because of the wide range of environments we have to consider.

Mr. PRITCHARD. Thank you, Mr. Chairman.

Mr. STUDDS. Mrs. Schneider.

Mrs. SCHNEIDER. Thank you.

I have been listening to Dr. Boesch, and also Dr. Schubel's testimony. To summarize what the two of you have been saying is that the priorities are not being appropriately set, and we have to put the scientific community back into the loop.

It seems to me that we have so many different advisory committees already in existence and, yet, you feel that our Government is not appropriately prioritorizing how funds should be expended. I have heard the mention of Sea Grant and the *Alvin*, estuarine programs, environmental quality, and I am not walking away with this collection of testimony with what you gentlemen can collectively define as being the top five issues that ought to receive top priority funding in this country.

Is there a consensus among yourselves?

Dr. SCHUBEL. Let me respond for the estuarine community. I think, certainly, the top priority that I would have is that we go back to trying to understand how estuaries operate. We did in the early 1950's solve many of the first order problems in estuaries. Much of the foundation of our understanding of the physics and biology of estuaries was laid during that period.

We have never gotten on to the next generation of questions, the much more difficult second order questions, and those that deal with the interaction of the biology, the chemistry, the geology, and the physics. That is the level of understanding that you have to have if you want to manage an estuarine system and make reliable predictions about what a proposed activity by society will have on that system.

We have been in such a hurry to do the applied research in response to a series of crises or perceived crises, that we have not even begun to attach that second generation of questions. I think that is a terrible mistake.

The Federal Government and the States have been extraordinarily generous in support of estuarine research, but I don't think we have been given the freedom to pursue the proper kinds of studies.

As to the nature of advisory committees, there are all kinds. There are citizens' advisory committees, there are citizens on the scientific advisory committees, et cetera. I think what we really need to do is to go back to multiyear funding of important estuarine systems through partnerships between the Federal Government and the appropriate States and that for early system an appropriate research plan is developed by the scientific community and is subject to scientific peer review. That can be done with a modest level of support and should be done well in advance of large expenditures of money for research.

If you came to me today and said you had $1 million tomorrow to do a study of Long Island Sound, we could not put together a good, scientifically sound study of Long Island Sound in a short timeframe to use that $1 million appropriately. If you said you have $100,000 for the next 12 months to design an appropriate study, and that if it stands the scrutiny of peer review by the best estuarine scientists in the country, then we will come up with funds for the research, we could do it. I would like to have that challenge.

Dr. BOESCH. I certainly echo Dr. Schubel's comments, but to broaden the perspective here, and I have no vested interest in the subject since I am essentially a coastal oceanographer, I think there is a growing consensus in the oceanographic community that the time is now to really approach some global ocean issues. These are not only of vast scientific interest but also of substantial practical importance with respect to climate, fisheries, and the like.

So, the National Science Foundation in its planning and the Board of Ocean Science and Policy is attempting to develop these consenses of ideas that you ask for.

Mrs. SCHNEIDER. I am curious as to why Dr. Schubel doesn't feel that you have adequate opportunity to do the appropriate kinds of studies. Is it that the Federal agencies have not provided access?

Dr. SCHUBEL. Well, when you think of the possible sources of funding, you immediately would think of going to the National Science Foundation for basic studies of Long Island Sound. And we have done that and have had some success. What I am saying in addition, however, that the next generation of questions requires interdisciplinary studies, number one, and regional studies, number two. You can't get around the need for these if the science is to be responsive to management needs. And these are going to have to go on for a number of years.

Those kinds of projects don't fare very well at NSF, and perhaps with some justification. So, I think that the appropriate funding vehicle has not been available. Now, it may be that with the new amendment to the Clean Water Act, if there are funds available for Long Island Sound, Narragansett Bay, Buzzards Bay, and Puget Sound and if the expenditure of those funds follow those criteria that I outlined, I think we could make significant contributions to science and to society. I am concerned that that won't happen.

Mrs. SCHNEIDER. Well, I think that we also share that concern in that the nature of the beast here in Congress and the way we do do business is, unfortunately, on a year-by-year basis. We hear the same kind of testimony before my Science and Technology Committee where the energy industry is saying "we don't know if we should pursue photovoltaics, or if we should go with congeneration because there is going to be Federal funding there; and is energy independence a national priority or not?"

We are in a situation here where we don't know to what extent oceanographic research and pursuit of the solutions to some of these problems is or is not a national priority.

Dr. Ross.

Dr. ROSS. I think one of the problems of the past has been the nature of oceanography. One of the best definitions I ever heard, by Henry Bigelow, was that oceanography is the application of all science to the phenomena of the ocean. For many years, we had biological oceanographers, physical oceanographers, chemical oceanographers—I think you know this very well—and each group would tend to push for its own priority. Rarely would they get together for a consensus.

I think we have seen a growth in the field, if I may, a maturity that now realizes that there are certain world-wide types of problems, techniques and technologies that are important to basic understanding of the ocean. I think you have heard some of these things mentioned today.

We didn't come up with five basic problems. We weren't charged with doing that, but I suspect if we were, we would have agreed to the satellite one, and I suspect we would have concluded that the world climate one was certainly very important. We may have differed after that, but we probably wouldn't have been too far away in our thoughts.

The point I am making is that it is a varied profession, and because of the different backgrounds of people, it is difficult to reach a consensus, but that is happening now. I think that is a very positive sign.

Mrs. SCHNEIDER. Very good.

I think that Dr. Schubel's reference to the annual Sea Grant funeral dance was certainly well characterized, but I must admit that for members of the scientific community to feel that you are on the outside is most unfortunate when you have the opportunity to communicate with your respective Members of Congress and also with the Federal agencies. It makes our job particularly difficult, not being scientists, to be able to determine where we want the funding to go.

That leads to my next question to Dr. Baker about the process that OMB uses in setting budget priorities. I would like to hear some of your comments on their process and how it impacts some of the things you were mentioning, such as infrastructure and other items.

Dr. BAKER. I can't really comment on that, because I don't know how OMB sets their priorities.

Mrs. SCHNEIDER. If you were in a situation to make recommendations of Federal dollars in this area, what kind of solutions might you recommend?

Dr. BAKER. I can answer that from the point of view of looking at the science that can be done that would be of benefit to the country, and I think we need to identify both economic and social benefits. Then, OMB would have to take such information and then weigh it against all other economic and social benefits to make its budgetary decisions.

When we look at oceanography, one of the very exciting things that we see now is the possibility for understanding whether the climate is predictable. Up to now, we have not even been able to see the way to do this. Now, with our understanding of processes that occur like this past year's El Niño, for example, or processes that occur when we look at the increasing carbon dioxide in the atmosphere, we believe that we have the tools to scientifically understand whether these systems can be predictable and if they are predictable, to built that system that actually does the prediction.

This has enormous implications for economics, for agriculture, and commerce. This is something that we could do. It is not an expensive proposition in terms of very large budgets, but rather an increment on the kind of activity that we have now. That is the kind of program that I think could be very well supported in terms of its benefits to the country.

Mrs. SCHNEIDER. Regarding the Joint Oceanographic Institutions that recently completed the research strategy for the study of the oceans by satellites for the next 10 years, to what degree has that study been shared with the other Federal agencies that are spending dollars for research in this area, and what has their response been?

Dr. BAKER. We worked very closely with the Federal agencies in putting together that report. The report was supported by NASA. We have worked closely with representatives from the Navy, with NOAA, and from the National Science Foundation. These are all agencies that have different pieces of the action in oceanographic satellites. The Navy has the N-ROSS satellite. NASA is planning for the TOPEX satellite that measures ocean circulation. NOAA will probably be responsible for a satellite that measures ocean color, and the National Science Foundation will be responsible for the basic research that takes place.

So, we have tried, and I think successfully, to work closely with the Federal agencies in putting together that report which, by the way, is one of the first and, I think, dramatic examples of all the disciplines of oceanography working together to put together a phased plan that will bring marvelous new results to oceanography.

Mrs. SCHNEIDER. We have the plan, and everybody worked together to develop it as a unit. However, the key question to the whole proposal is to what degree have the various Federal agencies, like NSF and the Navy, agreed to pick up on those recommendations and to include them in their research and operational programs?

Dr. BAKER. I think you can see in the fiscal year 1985 budget, the Navy satellite, N-ROSS, has been very strongly supported by the Navy and NOAA. As I understand it, that is in the budget. I believe that the TOPEX satellite is being considered as a very high priority for NASA in the fiscal year 1986 budget. We are working with the agencies for a new color imager for the 1987 budget.

One of the points of the strategy was to try to put together an oceanographic program, not one that would happen all at once, but to be a phased program that could be worked out with the agencies. The National Science Foundation has worked into their long-range plan the need for the research to go along with these satellites.

Mrs. SCHNEIDER. That sounds like a good response, and I thank you very much, all the panelists, for their insightful testimony. Now we will have the opportunity to ask those Federal agencies about their commitment.

Thank you, Mr. Chairman.

Mr. STUDDS. Thank you, Mrs. Schneider.

Dr. Schubel, you give high marks for intentions and low marks for performance to existing Federal and State programs to protect and manage estuaries. To follow up more precisely a question that Mrs. Schneider was discussing just a moment ago with you, regarding the recently enacted plan to fund cooperative pollution assessment and monitoring programs in Long Island Sound, Narragansett Bay and Buzzards Bay, how do we make sure this program works where others have not?

Dr. SCHUBEL. I think you should involve, at an early stage, the scientific community that surrounds those various estuaries and the scientific community also in other parts of the country. To date, I know that no one in my institution has been contacted about the Long Island Sound studies, and I know that no one at the University of Rhode Island has been contacted about the Narragansett Bay study.

So, I think, for starters, we need to involve the scientists in this. I think what we don't need, at this stage, is a detailed monitoring study of Long Island Sound, Narragansett Bay, or Block Island Sound, because, quite frankly, we wouldn't really know what to monitor, where to monitor, or at what frequencies in time and space to provide any useful data to managers who would be making decisions about these water bodies.

Mr. STUDDS. I think that answers the question.

Dr. Ross, has anyone at Woods Hole been approached with respect to a Buzzards Bay study?

Dr. ROSS. Yes, we have. This is maybe a little different case, but I think we were the ones that found some of the major problems there and called attention to them.

Mr. STUDDS. Right. This is very recently enacted funding, as you know. It may not be underway.

Maybe it is premature, but are you optimistic about the ability of this program to produce information that will be relevant to all of our estuarine areas, or do we have to have individual programs for every estuary?

Dr. ROSS. I am not an estuarine expert, but I will say one thing. One of the weaknesses in past estuarine research has been a tendency to focus on one estuary at a time. I think as we learn more about the general processes, we will then make great progress.

Dr. SCHUBEL. I think, certainly, there are a lot of things that we can learn that are transferable from one estuary to another. There is no question about that.

That level of understanding may be adequate for most of us as scientists. It really is not adequate, though, if you are an environmental manager who has to make a decision that is going to involve hundreds of millions of dollars or maybe billions of dollars on waste treatment, or other decisions that could affect the living resources and aesthetic qualities of an estuary for decades to centuries.

There you have to look at all of the processes individually and collectively and see how they are manifested in that particular estuary. The same processes operate in Long Island Sound as in Albemarle Sound. No question about that; but the relative importance of those processes may differ by orders of magnitude and the manifestations, may be entirely different.

Mr. STUDDS. Dr. Schubel, you bemoan in your statement the dominance of sociopolitical factors in estuarine research. I can't resist asking you whether, for example, you would characterize this subcommittee as a sociopolitical factor? [Laughter.]

Dr. SCHUBEL. I would never do that.

Mr. STUDDS. Please feel free to do so.

You criticize the transfer of responsibility for sophisticated scientific and technical decisions on how to attain research objectives into the hands of concerned, well intentioned people who lack the scientific and technical training needed to make sound scientific judgments.

What advice would you give to a humble and well intentioned policymaker who goes to the trouble of soliciting sophisticated scientific and technical advice from highly qualified individuals only to receive advice that is not only highly sophisticated and technically impressive, but also contradictory?

Dr. SCHUBEL. That is a tough question. I at least succeeded in writing something that got people's attention, I guess.

Most of these problems are very complex, as you have pointed out. I think what we need to do, though, is when we have a particular environmental problem, whether that is ocean dumping in the New York Bight, dumping of dredged material in the Chesapeake Bay or in Long Island Sound, or any of a range of other problems the first thing you have to do is to look at the full range of alternative strategies that you have at your disposal to deal with the particular problem. Then, you need the best, the most rigorous scientific and technical assessment of each of those alternatives—the environmental effects, the public health effects and the economic impacts.

It is only after the scientific and technical analysis is complete that the social and political factors should be evaluated by decision makers in arriving at a choice—in making a decision.

We don't do that. Usually, we take positions at the outset. We line up on one side or the other early on in the process, and from there on we expend most of our effort in defending our turf, and we never really get around to analyzing the alternatives.

We have to use science to look at the alternatives and then to put it into the other political realm.

Mr. STUDDS. Dr. Ross, are you satisfied that the State Department is presently doing everything it reasonably can to facilitate the access of U.S. scientists to opportunities for marine research in other countries?

Dr. ROSS. I would generally answer yes. This is not an easy issue. The State Department received considerable help recently when the President acknowledged the right of other states to control scientific research within their EEZ, and this committee helped to move him in that direction.

There was a little enthusiasm recently to develop bilaterial agreements, particularly between the United States and Canada. In my opinion, that may have been a little premature. Bilaterals can have a number of implications that aren't fully understood.

We have had problems with some specific countries like Trinidad and Tobago, and the State Department recently sent people down there to meet and talk about the problems, and that has helped the situation.

So, I don't think the problem rests right at this moment with the State Department. What I am concerned about, if I may, is a slightly different aspect of the problem, which may rest with the scientific community. I think their fears and concerns about working in this new regime may make those individuals who want to work in foreign waters pick the simplest and easiest places to work. Scientists have careers to rapidly develop. By doing so, we may make our worst fears come true. That is one of the reasons that I suggested a more aggressive approach to make it easier for scientists to try this process.

I am concerned that a young scientist would be hesitant to try to plan marine scientific research with a foreign country, to go through all the aggravation, and it is considerable, to develop a program, to implement the program, to succeed in the program, and be willing to try again. I think if we could find ways to make it easier, especially so that individuals don't have to learn all the information anew each time and can know what is available about the research style and behavior of other countries: this could be very helpful. At this moment I couldn't fault the State Department. They have been very helpful to me, and at this moment, I think they are doing a good job.

Mr. STUDDS. Do any members of the panel want to comment on Dr. Ross' proposal to establish an office of international marine science cooperation or to suggest a possible location in or outside of the Government for such an office?

Dr. HEATH. I think this is something that has been discussed and there are pros and cons for the location. I think at least everybody that I have had any contact with agrees that it is a good idea. It is a way of accumulating knowledge and wisdom that otherwise tends to get dissipated after each individual experience, as Dr. Ross points out.

I think one could argue that such an office would make more sense in the State Department than in an academic setting for some of the reasons that I pointed out earlier. Federal agencies and Government organizations tend to be longer lived than individual faculty who may be interested in a problem now but may have disappeared 5 years from now. Thus, from the point of view of longevity and availability into the future, there is some benefit in associating the proposed office with the State Department.

Mr. STUDDS. Dr. Corell, you emphasize in your statement the importance of the work that has been performed by the submersible *Alvin*. You also say that the *Alvin* is working at full capacity and that a number of outstanding scientific programs cannot be conducted because only one such vessel is in operation.

Then, you talk about the importance of having access to the Navy's *Seacliff*.

What exactly is the *Seacliff*, and what are its capabilities?

Dr. CORELL. The *Seacliff* is a vessel similar to *Alvin*, built about the same time, looks fairly much the same. It recently was converted to operate to 6,000 meters. The *Alvin* submarine is a 4,000-meter boat. At 4,000 meters, we can reach about half of the botton of the oceans of the world, and at 6,000 meters, it is in the high 90-percent region where we can get to the bottom of the ocean.

The *Alvin* review committee, UNOLS, the Navy, there have been many discussions over the past 2 or 3 years about providing access to the academic community to work aboard the *Seacliff* and her sister vessel, *Turtle*, which goes somewhat less in depth, in fact, less than *Alvin* itself. Those discussions appear to be moving in a very productive and positive direction. In fact, during the past couple years, there have been trading of pilots between the Woods Hole group, and the Navy group, and Subdep Group I in San Diego.

However, having access to that vessel is, I think, profoundly important for the academic community, because we can address questions like subduction processes and other questions in the deep sea, the manganese-nodule questions, things we cannot now do with the *Alvin*.

Mr. STUDDS. Who has access to the vessel at the present time, and is it adequate?

Dr. CORELL. It is operated by Op 23 and Subdep Group I of the Navy. It is primarily designed, as I understand it, to serve Navy mission needs, but there has been more openness recently to address the possibility of having more scientists from the academic community aboard.

I should note that there have been a number of academic scientists operating their programs from those vessels, but it is our opinion, particularly in the *Alvin* group, and the need for 6,000-foot capability, that access to that vessel needs to be expanded.

As indicated, discussions are underway, and the Navy appears to be much more receptive to that question. Secretary Lehman has put forth some new initiatives, as you probably know, in the Navy, for scientific research, and one of them is to explore more open access to these vessels for the academic scientific community.

Mr. STUDDS. I gather controversy has begun to develop over access by the scientific community generally to geophysical data concerning the EEZ, information to be collected, as I understand it, through the use of multichannel sonar devices, Sea-Beam or Sea-Mark. Would you or anyone else want to comment on the importance of this information to scientific research generally, and on the implications of any decision to classify this data rather than to make it available to the scientific community?

Dr. HEATH. The Board on Ocean and Science Policy has gotten involved with this to a minor extent. I think that the loss of that data set for scientific research would be unfortunate on several grounds.

We are fortunate that the U.S. margin, the exclusive economic zone, includes examples of a large number of major oceanic processes and particularly of geophysical processes and bottom types. In fact, most of the sea-floor types that are found in the oceans as a whole occur off the margins of the United States. So, we have the possibility of addressing an enormous range of problems, from mid-ocean ridges, to subduction zones, to various kinds of geochemical processes related to oil and gas formation and mineral formation within our own mineral formation within our own EEZ.

To force the scientific community to either repeat the kinds of observations that will be made and then classified or be forced to go elsewhere into some of the environments that Dr. Ross has described which can be difficult and certainly are much more expensive to get access to them our own EEZ seems to me to make no sense in terms of national priorities and the use of limited resources.

Mr. STUDDS. Mrs. Schneider, I have two more sets of questions. I would be happy to yield to you if you wish.

Mrs. SCHNEIDER. Thank you.

I would just like to make one brief request which will require a not so brief response. I would very much appreciate it if each of the members of the panel could prepare for me in writing, and perhaps for the other members of this committee for some point in the future, a list of the significant scientific problems and the new initiatives that we are going to have to face within the next 10 to 15 years. Second, I would like to ask for your recommendations as to how those initiatives might be funded, whether it be by the Federal Government, by private industry, or by cost-sharing arrangements. Who will pay?

The third thing I was thinking about is what benefit to society are we talking about?

Thank you, Mr. Chairman.

Mr. STUDDS. Beware of giving assignments to academics.

Mrs. SCHNEIDER. I have taken them for so long, it is about time I give them.

Dr. ROSS. You make the assumption that our society is going to be there in 10 to 15 years.

Mrs. SCHNEIDER. Well, I know I and my chairman are certainly working toward that end, and we have great confidence in the future. So, once again, let me request that these responses be only one or two pages. We are talking about preparation for Members of Congress, and please eliminate any voluminous proposals that you might have, just outlines of priorities.

Thank you.

[The scientists' statements may be found on pp. 193–202.]

Mr. STUDDS. Dr. Heath.

Dr. HEATH. I might just inject a comment here. The National Academy of Sciences Board on Ocean Science and Policy is now in the process of a study that is called "Oceans 2000." One of its objectives is to cover many of the questions you have asked. This study is not going to come out with a final report in less than a couple of years, I would guess, both because of the depth in which hope to address these questions and the glacial pace with which the Academy normally moves. Thus, we can give you a quick response right now, but I think the deeper response is a couple years away.

Mr. STUDDS. Just be grateful that wasn't a television reporter asking the question giving you 12 seconds to respond.

I am a little leery. Dr. Ross, I don't know if it was you or one of the others, but on a recent visit to Woods Hole, I was given an assignment. That is why I am particularly sensitive to this. Was it you who handled me the elementary textbook on oceanography?

Dr. ROSS. A few years ago, sir.

Mr. STUDDS. Yes; it was quite a few years ago, and I haven't read it. Sorry about that. Maybe yours is due when mine is.

Dr. Baker, you and several other panelists have commented both about the dramatic technological advances that have occurred in recent years and about the possibility that we will not, due to lack of resources, be able to take full advantage of the new technology. For example, satellites and other new kinds of instruments are capable of generating what you call a data explosion. The problem is, of course, that the generation of data helps little if we do not have the ability to process and make use of the information derived.

I have two questions. First, is this problem caused by a lack of trained people to design and operate data processing systems keyed to the needs of marine research, or is it a lack of the equipment itself, or is it both?

Dr. BAKER. I would say that we are looking at a problem which is as much the lack of trained people as it is the lack of equipment, but it is not just a question of the people and equipment. It is also a question of trying to understand how to solve this problem.

This is a major new problem that we are facing in science, and that is how to deal with large amounts of data and how to turn that data into useful models that we can use eventually for prediction. It is a problem of understanding and learning how to do something new. So, it is a combination of being able to draw on new technology with a sufficient body of trained people so that one can do this.

I think the scientific community in the United States recognizes this. I think the scientific communities in other countries recognize this. It is important for us to try to be on top of this problem if we are going to solve it.

Mr. STUDDS. Where do you see the solution coming from; Government, industry?

Dr. BAKER. I think it will be a combination of the academic community, industry, and Federal Government laboratories. For example, the problem has been addressed, to a large extent, by industry in their work with seismic data that they take for mineral exploration, petroleum. There are a lot of the ideas which are developed there which can be taken over to be used for the other problems. So, I think we will see an important role from private industry as well as the academic community.

Mr. STUDDS. OK.

Let me end with a general question that each of you can take a shot at if you like. Maybe it is sort of an oral preparation for more serious, penetrating thought about your assignment from the gentlewoman from Rhode Island.

Dr. Boesch said in his statement that: "We are on the threshold of substantial advances in our understanding and use of the oceans as a result of tremendous technological developments and the fusion of disciplines of ocean science."

My question to any or each or all of you is what the Government ought to be doing, if anything, to make sure that we move from standing at that threshold to crossing it and making full use of the benefits the new technology can bring. Is it a question, from the Government's perspective, of money, coordination, staying out of the way, or what?

Dr. HEATH. For lack of any other volunteers, I will step forth.

There are really two issues. One is the commitment of resources. We have already heard some of the costs associated with the NSF long-range plan which I think addresses in a very realistic way what is possible, what is imporant, what we are ready to do.

The other need from the Government, though, is a long-term commitment. In other words, as one gets into more global studies, more interdisciplinary studies, the possibility of solving something in 1 year or 2 years becomes vanishingly small. So, if a Government commitment only extends for 2 years, and then something else is in vogue and the attention is switched away, we are not going to see very much in the way of progress.

I believe you need both the resources and the long-range commitment.

Mr. STUDDS. Last call for anyone else.

Dr. SCHUBEL. Certainly, within estuaries, we have not seen that same explosion in technology that has allowed us to look at estuaries in new and different ways, because the time scales are so different in estuaries.

We need to develop new technologies. What we have seen is an explosion of data that has resulted from federally funded and State-funded monitoring programs.

I think what we need to do is to develop programs to translate the data into usable information and put this information into forms that managers can use when they are making environmental decisions.

Mr. STUDDS. Thank you.

Dr. BOESCH. I think, in response to your question, we need all of the above, basically. We need enhanced support. There is obviously need to use our resources better through more effective interagency coordination. In a certain sense, we also need Government to stand aside at the appropriate time, because there is a tendency, once a program develops in governmental agencies at all levels, for it to take a life of its own. A good idea is generated and then it becomes very formalized and stifles imagination coming from both within Government and outside of Government.

Mr. STUDDS. Dr. Corell.

Dr. CORELL. I think with the study that the National Science Foundation has done for its long-range plan, the Academy, NASA is also doing studies of this nature, there is a confluence of events that is going to allow us to look ahead very, very carefully at the scientific ocean research program of the next decade.

There is a certain psychological priority that comes from identifying that as something. We had the DOE program of some years ago, and it brought minds together. The Foundation was committed to it for a while. I personally think, and I hear many people talking about the fact that the 1990's might be a decade of ocean scientific research, and the mere statement of that will bring minds together, bring commitment in our academic institutions, will bring programs out of the Government and industry that would allow us to accomplish many of the objectives that you have heard from Dr. Baker and others of this panel today.

Thank you.

Mr. STUDDS. Dr. Ross.

Dr. ROSS. Well, I think everbody has said what I would have said, so let me add something different.

The United States has recently acquired a territory that is greater than that any country has ever acquired—its own exclusive economic zone. I am startled that this has not captured the imagination of the Government: to look at our oceans and see how we can use them better, and to capitalize on this expansive resource and the scientific opportunities it presents.

Mr. STUDDS. Did you just use the phrase, the imagination of our Government?

Dr. ROSS. I should have known better.

Mr. STUDDS. No, I just wanted to be clear.

Dr. ROSS. Well, it is a wonderful opportunitity, combined with the new technologies that you have been hearing about today and some of these programs that we may enable us to enter a new and exciting area of marine science.

Mr. STUDDS. Dr. Baker.

Dr. BAKER. Let me just emphasize the need for coordination. I think we have seen very important things happen in the past few years, both on the side of what has been supported by the Government and also what has been happening in private industry. I think that as we look toward the next few decades, we are looking toward an effective program that will only be effective if we do have the proper coordination within the Government, that is, between NOAA, NASA, the National Science Foundation, and the Navy, and also the right kind of partnership between the Government and private industry.

I think, without that, we won't be able to make our moves, but with that, we have a change of having some dramatic new understanding of what the oceans are all about.

Mr. STUDDS. Thank you, sir.

I am going to take the liberty of asking one personal question to set the stage for the academic response that is due.

Dr. Schubel, I can't resist this. One of the things your testimony did was make me rethink a word that I had taken for granted and assumed I knew the meaning of, namely, estuary and estuarine, which we certainly in our more lighthearted manner around here use regularly. This is a test of my staff. You can be cold, and cruel, and academic in responding to it. I am going to read you a definition and I want you to tell me if it can be improved upon.

Dr. SCHUBEL. Is this from Dave Ross' book? [Laughter.]

Mr. STUDDS. You do not know from whence it comes. It consists of three sentences, the last of which is clearly my favorite:

> Estuary is the usually muddy area found along the ocean coast at the mouth of rivers, creeks, or other fresh water streams flowing into the ocean. These areas are subject to extreme fluctuations in temperature, salinity, and pollutant loading. Generally, they are a salty medium but can become almost fresh during low tide and stormy conditions.

Dr. SCHUBEL. I think it could be improved upon. [Laughter.]

Thank you.

[More laughter.]

Mr. STUDDS. Thank you.

Thank you very much, members of the panel. You have been very patient. We appreciate your contribution, and we look forward to a more leisurely opportunity to read your statements in their entirety.

We go now to our second panel comprising what I guess has to be called the Government.

If the five representatives of the Federal Government who are on panel two would take their places, I will describe the rather unusual procedure we are going to follow.

As all of the witnesses have been forewarned, in the interests of time, we have chosen to move directly to questions, and to forgo the normal procedure of prepared oral testimony from the administration panel. We do, however, have your written statements. They are being ardently sought after, as you can see behind you, and they will be included in the formal hearing record.

[The statements follow:]

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STATEMENT OF PAUL M. WOLFF, ASSISTANT ADMINISTRATOR FOR OCEAN SERVICES AND COASTAL ZONE MANAGEMENT, U.S. DEPARTMENT OF COMMERCE

Mr. Chairman and Members of the Subcommittee:

I appreciate the opportunity to discuss with you oceanographic research in the National Oceanic and Atmospheric Administration (NOAA).

The National Oceanic and Atmospheric Administration seeks improved delivery of products and services to the marine user community. To accomplish this we must build upon oceanographic and meteorological data and understanding of the ocean environment. These are the result of the basic and applied research efforts of the oceanographic community and NOAA itself.

Oceanographic research should support the NOAA mission. As one indication of this commitment, NOAA maintains science and oceanographic expertise within our Environmental Research Laboratories, Fisheries Laboratories and aboard NOAA Ships. In addition, many of NOAA's programs themselves have staff engaged in specific, applied research projects.

Better coordination of marine research and its results are continuing efforts. One of my six major program objectives as Assistant Administrator of the National Ocean Service (NOS) is to increase cooperation within government and with the private sector.

My testimony today describes briefly a number of NOAA's current efforts involving other Federal agencies in cooperative research programs. It also addresses the future direction in oceanography at NOAA including efforts underway to map the newly proclaimed exclusive economic zone (EEZ); increasing the use of remote sensing capability; and the operation of NOAA's fleet.

<u>Coordination of Federal Marine Research Capability</u>

NOAA participates in a number of multi-agency coordination efforts. Significant examples include:

- NOAA Administrator, Dr. John Byrne, last spring reactivated the Subcommittee on Marine Research (SMR) of the Committee on Atmosphere and Oceans established under the Federal Coordinating Council for Science, Engineering, and Technology. NOAA chairs the SMR, which has met three times so far this year. Senior representatives from eleven agencies or departments have addressed the overall Federal marine science budget, remote sensing of the oceans from satellites, EEZ surveys and near-shore remote sensing from aircraft.

Federal efforts in the EEZ, and the needs and capabilities of the marine community in the area of ocean (near-shore) remote sensing from aircraft.)

- NOAA has specific statutory responsibilities to coordinate Federal marine pollution research, development and monitoring activities. NOAA's National Marine Pollution Program Office (NMPPO) prepares, on a triennial basis, a five-year Federal Plan which describes the status of related Federal agency ocean pollution programs and includes recommendations on priority research needs. Appendices to the Plan provide detailed information on agencies' marine pollution activities, including an inventory of facilities and equipment used to conduct these activities. Action Plans are being developed by NMPPO to specify detailed research needs and agency plans for ocean disposal of radioactive waste and ocean dumping of municipal and industrial wastes.

- NOAA also participates in the Federal Oceanographic Fleet Coordination Council (FOFCC), along with other agencies with fleets -- the National Science Foundation (NSF), Navy, U.S. Coast Guard, Environmental Protection Agency, and U.S. Geological Survey (USGS). The Council reviews operations and management methods, recommending common standards and approaches; seeks to improve planning, coordination, and communication of operators of the U.S. research fleet; and disseminates operating schedules.

NOAA has signed in a number of specific interagency agreements to improve our coordination in the oceanography area. Examples are:

- Recently initiated efforts to map the Exclusive Economic Zone (EEZ) are the subject of an agreement between NOAA and USGS, signed in April 1984.
- Several hundred memoranda and letters of understanding cover a range of activities with the Navy from routine training and exchange of personnel and facilities, to major data exchange and cooperative oceanographic research efforts. We are developing a broad agreement with the Navy under which these and other individual activities can be carried out in a simplified manner.
- The Outer Continental Shelf Environmental Assessment Program (OCSEAP) is a NOAA program supported by the Minerals Management Service (MMS), DOI. Because of our technical and logistical expertise, in the Alaska region NOAA conducts the assessment work on the effects of oil and gas development under a special agreement which is to renewed in 1985. The purpose of the OCSEAP effort is to provide information about the OCS environment and possible effects and impacts. Until now, MMS has operated its own environmental assessment programs in other regions.

- Various research projects are carried out under a Joint Agreement between NOAA/Environmental Research Laboratories (ERL), the Naval Research Laboratory, and NASA/Goddard. The purpose of this agreement is to assure more effective utilization of space technology and to improve the knowledge and understanding of ocean and atmospheric remote sensing.

- NOAA has a general memorandum of understanding with the Environmental Protection Agency for program coordination and information exchange. Under the broad terms of this agreement, we provide scientific support in response to spills and toxic hazardous waste clean-up.

NOAA is involved in several oceanographic programs of multi-agency scope, for example:

- The Tropical Ocean and Global Atmosphere (TOGA) project is an international research project set up as part of the World Climate Research Program under the auspices of the World Meteorological Organization, the Intergovernmental Oceanographic Commission, and the International Council of Scientific Unions. TOGA seeks to establish an understanding of the complex relationship between large periodic variations in the tropical Pacific and Indian Oceans (the so-called El Nino-Southern Oscillation) and climatic anomalies in many parts of the world.

NOAA coordinates the TOGA efforts of the NSF, the Department of Defense (DoD), National Aeronautics and Space Administration (NASA), domestic meteorological and oceanographic research institutions, and universities. Methods are being worked out for the coordinated review of research proposals.

o NOAA has drawn together its fisheries and oceanographic research capabilities in a program currently referred to as the Fisheries-Oceanography Coordinated Investigations (FOCI). NOAA seeks to include other Federal agencies and state and university participation to coordinate research on the effects of environmental changes on fisheries. The goal of this research is to quantitatively measure the effects of ocean processes and hydrodynamic features on the survival of eggs and larvae, and on later juvenile life stages. The results could be used in developing predictive numerical equations to assist in providing much-needed lead-time for planning and implementing improved management, harvesting, and processing of these resources.

o NOAA is spearheading an international research effort similar to FOCI under the sponsorship of the Intergovernmental Oceanographic Commission (IOC), with the cooperation of the U.N. Food and Agriculture Organization (FAO). Both developed and developing nations collaborate in research on fisheries recruitment problems in similar, analogous, marine ecosystems throughout the world.

- The World's Ocean Current Experiment (WOCE) is being planned to determine the general circulation of the ocean and its relation to global climate. This major project is expected to begin in 1990 or 1991.

Mapping of the Exclusive Economic Zone (EEZ)

In response to President Reagan's March 10, 1983 proclamation declaring the U.S. Exclusive Economic Zone, NOAA and USGS have initiated a multi-year cooperative program for bathymetric su[illegible]ing of the 200-mile contiguous zone.

High resolution bathymetric data is being gathered with state-of-the-art swath mapping systems to facilitate understanding, development, and conservation of this vast national resource. Initial surveys are being conducted off the west coast, and will cover the outer continental shelf, slope and upper rise off California, Oregon, and Washington. Bottom sampling for radionuclide background studies by the Environmental Protection Agency also is included in the present work. Proposals are being considered to incorporate a complete suite of geophysical measurements as well as measurements of meteorological parameters and physical, biological, and chemical oceanographic parameters. An announcement has been made in professional journals of the opportunity for researchers to utilize the ship time to conduct compatible investigations in conjunction with these surveys. A workshop (December 1984) and conference (Spring 1985) are being planned to ensure that the design of these surveys is responsive to the needs of other Federal agencies, universities, and the private sector. An NOS plan outlining the scope of this initiative currently is in draft form.

Some issues of coordination and exchange of the data generated from the surveys of the EEZ remain to be resolved. A working group with representatives from NOAA and the Defense Mapping Agency currently is negotiating on the question of whether EEZ bathymetric data will be classified.

Remote-Sensing Capability in Oceanographic Research

Significant advances in our understanding of the ocean and its role in global climate will require the synoptic global perspective which can be provided by satellites. Major projects such as TOGA, WOCE, and studies of the ocean's role in carbon dioxide warming are dependent to some degree upon satellite observations. Parameters such as sea surface temperature and ocean surface winds provided by satellites open vast opportunities to understand the ocean processes which influence fisheries recruitment. Examples of recent successful applications of remote sensing data are:

o The NSF-sponsored Warm Core Rings project, which used sea surface temperature data and coastal zone color scanner (CZCS) information to study the physical dynamics, biology and chemistry of warm currents from the Gulf Stream.

- Work by NOAA's National Geodetic Survey application of SEASAT altimeter data to the Nation's geodetic reference system. The data also has been used to infer the presence of large scale features in unmapped ocean areas.

A coordinated research strategy for the decade 1985 to 1995 was prepared by a consortia of oceanographic research institutions summarizing the requirements for oceanography from space. These requirements are focused more on relatively short duration experiments, instruments of new design, non-real-time use of data, and undefined ground systems to receive transmissions.

By contrast NOAA's satellite observation requirements for our operational needs are for long term, continuous, routine monitoring in order to produce real-time products and services and disseminate them to the users.

<u>The NOAA Fleet</u>

The NOAA Fleet provides a vital oceanic data collection and research capability in support of many varied marine science projects. The vessels are in excellent condition. The hulls will be sound through the year 2000. We do not need to replace the existing fleet until the late 1990's. We are monitoring ship planning by the National Science Foundation and Office of Naval Research, and others to be alert to developments which could improve the efficiency of our mission. Meanwhile our efforts are on new ship equipment and data collection systems to

Our current efforts include:

- SEABEAM - This acoustic mapping system produces high-resolution contour charts of the seafloor, in real-time, and is useful in producing detailed bathymetric surveys of the EEZ. The system is currently deployed aboard NOAA Ship SURVEYOR.

- Shipboard Environmental Data Acquisition System (SEAS) - SEAS provides acquisition, formatting, and transmission of shipboard marine weather observations and Expendable Bathythermograph (XBT) ocean temperature profiles. SEAS semi-automated instrumentation will be aboard ships of the NOAA Fleet to increase data sampling coverage and to ensure a timely data return via satellite of meteorological and oceanographic information.

- Global Positioning System (GPS) - The NAVSTAR GPS is a DoD-funded, satellite-based navigation and time distribution system which will provide precise, continuous, all-weather, common grid, worldwide navigation, and timing information to aid land and sea users. New program requirements such as bathymetric surveys in the EEZ and global climate-related oceanographic programs, can be met with GPS by providing highly accurate navigation and positioning information worldwide.

- **INMARSAT (International Maritime Satellite organization)** - INMARSAT terminals will provide a highly reliable voice communication system for NOAA ships operating in remote areas. These systems utilize satellite technology to provide a direct communications link to meet operational requirements and to facilitate real-time monitoring of direct transmission of marine data. Two units will be installed aboard the NOAA Ships RESEARCHER and DISCOVERER by February 1985.

These improvements are being installed beginning in FY 1984, funded by inter-agency transfers, savings from personnel reductions, and generally without new budget initiatives.

NOAA is actively promoting the efficient cooperative use of its vessels. We will actively solicit academic institutions and Federal and state agencies to promote use of the Fleet on piggyback, ancillary, or shared projects. In addition, NOAA will contact local officials and news media representatives in areas of planned and current vessel operations. We are already improving vessel productivity through taking additional data and utilizing sea days gained through improved vessel performance for additional project-related activities.

Future Direction

NOAA is charged with analyzing and predicting oceanic and atmospheric components of the Earth's environment. The importance of this global, integrated air-sea approach is reflected in NOAA's five line offices - the National Weather Service; the National Marine Fisheries Service; the National Ocean Service; the Environmental Satellite, Data and Information Service; and the Office of Oceanic and Atmospheric Research.

Our emphasis is on improved services; research must support this service mission.

Mr. Chairman, this concludes my prepared statement. I will be happy to answer any questions you may have.

STATEMENT OF

DR. M. GRANT GROSS
DIRECTOR, OCEAN SCIENCES DIVISION
NATIONAL SCIENCE FOUNDATION

OCEAN SCIENCE RESEARCH SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION

My name is, M. Grant Gross, I am Director, Division of Ocean Sciences, National Science Foundation.

Oceanography in the National Science Foundation is primarily supported through the Division of Ocean Sciences (OCE). Other support is provided by the Divisions of Polar Programs, Earth Sciences, Atmospheric Sciences and Biotic Systems and Resources, among others.

OCE in FY 1985 has a budget of approximately $120M. This amounts to about half of all ocean research conducted at U.S. universities and about 70% of the nation's basic academic ocean research in the U.S. In 1985, OCE expects to Fund about 730 research projects, about 40% of the proposals received. These funds will support about 600 of senior scientists, about 100 man-years of post-doctoral research and about 350 man-years of student support. Nearly $10M is expected to be spent in FY 1985 on instruments and equipment by the projects supported.

Ocean research requires expensive shared-use facilities: ships, submersibles, and a deep-ocean drill ship. Along with ONR and other Federal Agencies, NSF supports operations of the nation's academic research fleet. In 1985, operations of 24 research vessels will be supported. These vessels are operated by 19 institutions on all US coasts, including Alaska, Hawaii, and the Great Lakes.

Research ships are the backbone of ocean research. The supporting Federal Agencies seek to insure that each vessel is energy-efficient and equipped with latest navigation equipment, modern instrument-handling systems, and satellite transmission facilities to handle communications and data transmission. Working with MARAD and ONR, NSF regularly inspects academic vessels, to insure their safe and efficient operation.

The function of ships is changing in a fundamental way. Ships are now floating laboratories, providing groups of investigators with facilities needed to study ocean phenomena. While the present fleet consists primarily of conventional ships, their replacements may well be based on different types of hulls. Some replacement ships will likely be dedicated to functions such as seismic investigations of deep ocean basins.

The deep-diving submersible ALVIN and its recently converted tender, ATLANTIS-II, can now be used in remote areas of the ocean, previously beyond the working range of its former tender. With its new tender, ALVIN has made as many dives in five months as it previously made in a year. U.S. oceanographers are now actively seeking to obtain access to a submersible, such as the Navy's Sea Cliff, which can dive to 6000M. This will permit them to research half of the ocean beyond ALVIN'S depth limits.

Ocean sciences are changing rapidly, primarily as a result of advances in computers and in satellite-remote-sensing. Over the next few years, NSF will support acquisition of a Class VII supercomputer for the National Center for Atmospheric Research (NCAR). One fifth of the time available on this computer will be devoted to ocean modeling. At the same time, NSF and other funding agencies, will be funding investigators to equip themselves to communicate from remote locations with this and other such computers which may be located on the other side of the country.

Satellite-remote-sensing is now providing observations necessary to study ocean processes on appropriate time and space scales. Oceanographers can now study ocean processes on regional and even global scales. Satellites for ocean sensing are in orbit. NOAA, Navy and NASA, and Japan, France and the European Space Agency plan to launch satellites that will provide data useful for ocean studies. NSF and NASA plan to insure that U.S. academic oceanographers are able to use this data stream in their research projects.

Oceanographers in the U.S. and around the world are now planning the next generation of studies to take advantage of these new opportunities. In projecting future trends in U.S. ocean science, NSF staff has identified two important areas of future scientific emphasis. The first, Global Ocean Studies, deal with flows and mass water, balances, energy, and various biological/chemical substances and their effects on productivity of the oceans and climate changes.

The Global Ocean Studies will make use of satellite observing capabilities, coupled with in situ observational programs and guided by numerical modeling, using the new supercomputers, to investigate:

- Global ocean circulations - What are the main flow patterns, their variability? How are they related to climate and productivity?

- Open-ocean fluxes - What are the mechanisms and rates at which chemical and biological agents are transported through the ocean?

- Coastal ocean dynamics and fluxes - How does the coastal ocean operate and how do materials move through it?

- Predator recruitment mechanisms - What controls the survival, maturation and reproductive capacity of larger organisms in the ocean?

The second major area is the study of earth's crust under the ocean using ocean drilling combined with the latest seismic techniques adopted from industrial practice. The two major components of this study are:

- Submerged continental margin.

- Oceanic lithosphere and mid-ocean ridge processes.

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Such activities require equipping academic institutions with the latest geophysical instrumentation, as well as one or more fully-equipped ships to conduct state-of-the-art seismic studies of ocean basins and continental margins. One of the most intriguing aspects of this study is the idea of building instrument systems to permit long-term observations (years to tens of years) on active segments of mid-ocean ridges. In this way, growth of oceanic plates could be observed directly. Scientists can then answer questions about changes over time in the various processes active on mid-ocean ridges.

These two areas of emerging emphasis -- integrated, large scale studies of the global oceans and basins -- are developing a broad base of support within the ocean science community.

- They are building on a firm foundation of recently acquired knowledge.

- They reflect a growing ability within the community to deal effectively with scientific problems of this sort which are large in scale and interdisciplinary in nature.

- They provide a solid and challenging intellectual basis for the scientific use of extremely powerful new technologies of remote sensing, supercomputing, and seismic imaging in ocean research.

- Coupled with these technologies they provide the

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exciting opportunity for a truly unique period of scientific progress in understanding the circulation and mixing of the oceans, the large-scale interaction of the oceans and atmosphere, the flux of materials through the oceans, and the structure and formative processes of the ocean basins.

And, I believe it is fair to say that this scientific progress will in the long run prove to be an essential underpinning for dealing effectively with the important societal concerns relating to weather and climate prediction, living and mineral resources, and environmental pollution.

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The Oceanography Report

H.M.S. Challenger [illegible]

The Oceanography Report
The focal point for physical, chemical, geological, and biological oceanographers

Associate Editor: Arnold L. Gordon, Lamont-Doherty Geological Observatory, Palisades, New York, 10964 (telephone 914/359-2900 ext. 325)

Ocean Sciences Peer Review in NSF

PAGES 1202-1203

Robert E. Wall

Introduction

Someone—I believe it was a German statesman—once said that there were two questions to which most people did not really want answers: What goes into sausage? and How are government decisions made? I am sure there is some truth here. Although I'm not familiar with what has been happening in the area of sausage making, there have been many discussions and several recent studies about the use and effectiveness of peer review in federal agencies deciding what research to support.

This article is precipitated by these recent studies, by the availability of quantitative peer review data in the Ocean Sciences Research Section (OSRS) of the National Science Foundation (NSF), and by continuing questions and statements concerning the peer review process that suggest some misunderstanding about what it is and how it works. My intent in this article is to describe the general process of peer review used in OSRS and to explain some of the variations in that process. Data and statistics on proposals considered for support with Fiscal Year (FY) 1981 funds help illustrate the process.

Background

By any measure, the primary activity of the NSF is the support of research projects across the spectrum of the scientific disciplines. A major element of this activity is the evaluation of unsolicited research proposals in order to decide which of these to support. Furthermore, a primary factor in reaching these decisions is the advice obtained through proposal peer review.

Although peer review has always been used by the NSF, the process was given some formal ground rules in the late 1970's. The most significant of these included the following points:

1. Establishing four general criteria for use in evaluating NSF research proposals: (1) research performer competence, (2) intrinsic scientific merit, (3) utility or relevance, and (4) effect on the infrastructure of U.S. science and engineering.
2. Distinguishing different weightings for these criteria depending on the nature of the proposed research. Thus, for basic research proposals, criteria 1 and 2 above are given the most weight.
3. Requiring peer review of essentially all proposals, excepting those for supplemental support or for committed renewal support on continuing grants.
4. Requiring that a minimum standard peer review be identified for each program, while recognizing variations in peer review practice in different parts of the NSF (e.g., ad hoc mail review only, panel review only, combinations of mail and panel review).

With regard to the last of these, the minimum standard peer review requirement for programs in OSRS is ad hoc mail review. However, for 60-80% of our peer-reviewed proposals, we obtain additional advice from proposal review panels. This allows us to make decisions on the basis of advice solely from mail reviewers while retaining the value of panel review where such additional advice may be helpful.

The Process

In practice, the OSRS peer review process is a continuous one with pulses of activity associated with our proposal review panel meetings. It is most convenient to describe it by using data covering an entire fiscal year cycle. I will use our proposal data file for FY1981 (October 1, 1980, through September 30, 1981) because it is the most recent year for which proposal statistics are relatively complete and accurate. This file contains information on just over 900 proposals that were considered for support from our FY1981 funds. About 200 of these proposals were for committed renewals of continuing grants or for supplemental support to existing grants. The remainder, slightly more than 700, were peer reviewed and were subsequently funded or declined. Altogether, these peer-reviewed proposals requested almost $125 million. Available FY1981 funding totaled about $37.5 million.

While proposals requiring peer review are accepted at any time, their submission and evaluation, and the earliest start dates for those funded, are tied rather closely to our proposal review panel meetings. For proposals considered for FY81 funding, these meetings were held in late July 1980, mid November 1980, and late April 1981. Figure 1a illustrates the distribution of peer-reviewed proposals considered as a function of date received. Figure 1b shows the distribution of these proposals by time in months between receipt and final action for awards and declines separately. The distribution of awards by start date is shown in Figure 1c. The minor discrepancies in the Figure 1 totals relate to the structure of the data file coupled with slight differences in the programs used to query the file.

Note that well over half of the peer-reviewed proposals considered for support with FY81 funds were submitted in FY80. Also, the distribution of processing time for awards reflects a combination of factors involving the desired start date, staff workload, and the time required for peer review, negotiation, documentation, higher level approval, and generation of the formal grant instrument in NSF's Division of Grants and Contracts. For declines, the distribution reflects a somewhat different combination of factors. While staff workload and time for peer review remain important, time required for administratively processing a declination is 30-45 days less than that for an award. In addition, formal action on declines is frequently taken as quickly as possible to provide reviewer feedback to the principal investigator. Decisions on some proposals are deferred until final program budget levels are known and decisions on support levels for competing proposals have been made. This causes some of the longer processing times indicated for declines and for some of the awards as well. Finally, start dates for awards show a relatively even distribution with very modest peaks in November, January-March, and July-September. These peaks are of course related to the strong pulses in proposals received, attenuated by the broad variations in processing time.

As proposals are received, they are assigned to the most appropriate program for administrative and technical responsibility. In OSRS these programs are aligned with the four budgetary program elements of physical oceanography, marine chemistry, submarine geology and geophysics, and biological oceanography.

An OSRS program staff member, after an initial reading, selects mail reviewers for each proposal. In general, reviewers are chosen because they have technical expertise in the area of the proposed research. The number and nature of mail reviewers solicited varies considerably depending on such factors as the breadth, cost, and character of the proposed work; in-depth staff expertise in the area of research; and anticipated or realized low return rate from reviewers. Staff members make a sincere effort not to overburden any single reviewer. Table 1 illustrates the distribution of mail reviews requested and received for all FY81 peer-reviewed proposals.

As was mentioned above and shown in Figure 1, most proposals requiring peer review are submitted to meet a target date for one of the three proposal review panel meetings held each year. These target dates are set far enough in advance of a panel meeting so that any proposal received by that date is normally assured of panel review, if warranted, at the next scheduled panel meeting. Proposals received after the target date may be deferred to a subsequent panel meeting. Decisions on the review schedule for such proposals are made by program staff and depend primarily on the program workload and the

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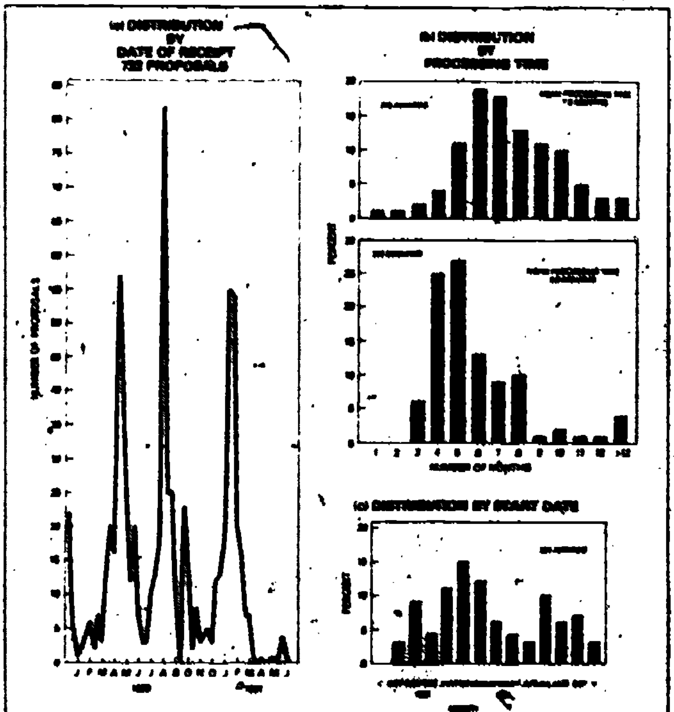

Fig. 1. Distributions of peer-reviewed proposals considered in the Ocean Sciences Research Section for FY1981 funding by (*a*) date received, (*b*) length of processing time for awards and declines, and (*c*) start dates for awards.

time available to obtain mail reviews prior to the upcoming panel meeting.

An OSRS proposal review panel generally consists of 16–18 panelists with 3–5 members for each of the four disciplinary areas. Most panelists are appointed as 2-year consultants to the NSF, but some are brought in as experts for a single panel meeting. Both consultants and experts are selected by program staff with informal advice from current panelists. Consideration is given to technical, geographic, and institutional breadth and balance and to the breadth of the individual's experience. Over the past 4 years some 50 scientists from the oceanographic research community have served on these panels.

Prior to a panel meeting, the panelists in each disciplinary area are sent copies of all proposals being considered by the program. A discussion leader (usually a panelist, but occasionally a staff member) is identified in advance for each proposal.

Before a panel meeting and as mail reviews are received, the program staff identify those proposals that in their judgment do not warrant panel discussion. At the panel meeting, these proposals are not reviewed unless a panelist questions the judgment and wishes to discuss a specific proposal. This practice allows the panel to focus its attention and spend its limited time on those proposals where additional advice would be useful to both program staff and the principal investigator. Table 2 provides a summary of the FY81 peer-reviewed proposals that were not reviewed by panel. For the most part, the decisions on these proposals were clearly indicated by the advice contained in mail reviews. In OSRS the numerical rating scale used is 1 for excellent, 2 for very good, 3 for good, 4 for fair, and 5 for poor.

During a meeting, panelists for the most part meet and deliberate in four disciplinary subpanels with appropriate program staff. Staff members provide them with an overview and status report on program budgets, recent awards, future commitments, and a proposal discussion schedule for the meeting. Discussions of individual proposals vary considerably in length of time, number of active participants among staff and panelists, and points of focus. In addition to the proposal itself, panelists have available the mail reviews of the proposal. Normally, following discussion, the panelists rate the proposal, using the same scale as mail reviewers. With very few exceptions, the range of ratings by panelists on a proposal following discussion is no more than 1.0. While many proposals are rated on an 'as proposed' basis, a significant number are rated by the panel, assuming modifications would be made in the research project if it were ultimately supported. Deleting a specific component, changing the duration, or adjusting the level of effort are common examples. In most instances such modifications would involve changes in funding levels if the proposal is supported.

Some Special Cases

While the above process is used for most proposals, there are three general categories that warrant special discussion because they receive somewhat modified treatment. These are individual inter- or multi-disciplinary proposals, multi-component 'big science' proposals, and doctoral dissertation proposals.

Inter- or multi-disciplinary proposals submitted by an individual researcher or by two or three collaborating researchers are identified as such by OSRS staff upon receipt in the NSF. In general, these proposals contain research objectives and/or techniques that in some way cross the boundaries between NSF programs. Although administrative responsibility for such a proposal is assigned to one specific program, staff from each of the involved programs cooperate in assigning mail reviewers who individually or collectively have the necessary expertise to evaluate the proposal.

Panel review of these proposals follow one of two courses. In some interdisciplinary areas such as the interactive biology and physics in frontal systems or the geochemical processes of the seafloor, there may be enough proposals (5–10) to warrant review by a formally designated interdisciplinary subpanel. Such subpanels are scheduled for a 2- to 3-hour period during the 2-day panel meeting. The remaining interdisciplinary proposals, most of which are one of a kind or are primarily pertinent to one disciplinary area with only minor implications to another area, are evaluated by the primary disciplinary subpanel augmented by the addition of an appropriate

TABLE 1. Mail Reviews Requested and Received

Number of Reviews	Percent of Proposals with This Number: Requested	Percent of Proposals with This Number: Received	Overall Averages
1	0%	1%	
2	1%	4%	average number of reviews
3	3%	14%	requested per proposal: 5.8
4	4%	20%	
5	14%	33%	average number of reviews
6	36%	15%	received per proposal: 4.6
7	13%	[illegible]	
8	[illegible]	2%	average percentage returned 79%
9	[illegible]	0%	
10 or more	[illegible]	1%	

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TABLE 2 Distribution of Proposals Not Reviewed by Panel Versus Average Mail Reviews

Average Mail Review Rating	Total Number of Proposals	Number Not Reviewed by Panel			Percent Not to Panel
		Awards	Declines	Total	
1.0–1.4	39	10	0	10	26%
1.5–1.9	107	16	0	16	15%
2.0–2.4	229	25	4	30	13%
2.5–2.9	190	8	33	41	22%
3.0–3.4	95	1	39	40	42%
3.5–3.9	34	0	21	21	62%
4.0–4.4	6	0	4	4	67%
4.5–5.0	5	0	5	5	60%
Totals	785	61	104	165	23%

panelist or two from the secondary subpanel. Considerable staff planning and effort go into arranging for the discussion of these proposals during panel meetings.

The second category of proposal that is treated somewhat differently is the multi-component 'big science' proposal. These proposals vary in the way they are structured and they vary a great deal in the size, scope, costs, duration, and numbers of researchers and institutions involved. In general, however, they contain some form of an overview document and a set of individual component proposals. The overview document attempts to describe the scientific problems, goals, and objectives being pursued, to lay out the general approach to be followed; to describe the multiple components involved; and to provide the overall context within which to evaluate the component proposals.

These multi-component 'big science' proposals are administratively assigned to the most appropriate program or programs. One program staff person is assigned overall responsibility, and other appropriate staff members are involved in the assignment of mail reviews and in the panel evaluations. In most instances, mail reviewers are asked to review one or two of the component proposals and are provided with the overview document and/or a set of abstracts from all component proposals. An assessment of the overall program is also usually solicited from them.

Panel review of these proposals is usually handled by an ad hoc panel specially convened for evaluating both the overall proposed program and the individual components. Occasionally, however, such proposals are dealt with as a part of the regular panel meetings for reasons of efficiency and when the proposal workload and review schedule allow. In either case, scientists whose expertise matches the work proposed are selected by NSF staff to serve on the review panel.

The third special category of proposal is for support of doctoral dissertation research. Proposals in this category are restricted in size and costs, are usually reviewed by only two or three mail reviewers, and often are not taken to panel.

Some Statistics

With the preceding as background, it is informative to look at some statistics for FY1981 peer-reviewed proposals. Figure 2 shows the distribution of awards and declines by average mail review rating. Figure 3 shows similar distributional data by average panel rating for a large subset of the same proposals. In these figures, an award/decline cutoff by the numbers is shown. This indicates the average mail or panel review rating above which all FY81 proposals would have been funded and below which all would have been declined if average ratings (mail or panel) alone were considered and if the number of awards paralleled the dollars awarded. The area of overlap of the two distributions in each figure (the dotted portion of the figures) graphically depicts the extent to which average ratings by mail or panel do not reflect the final decisions made by NSF staff. Some things to note in these figures include (1) average mail review ratings are a significant indicator of probable success; (2) a sizeable number of final award/decline decisions (146 total or 21%) differ from what would have been the case if average mail review rating were the sole determinant; (3) average panel ratings are a significant indicator of probable success, more so than average mail review ratings; (4) a number of final award/decline decisions (68 total or 14% of panel-rated proposals) differ from what would have been the case if average panel rating were the sole determinant for panel-rated proposals, and (5) the average panel ratings tend to be more discriminatory than average mail ratings, showing more bimodality, a higher average rating for awards, a lower average rating for declines, and larger standard deviations.

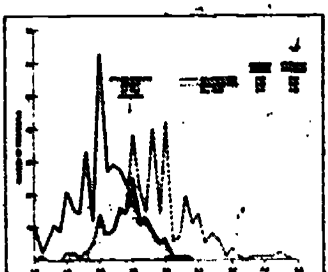

Fig. 2 Distribution of FY1981 peer-reviewed awards and declines by average mail review rating.

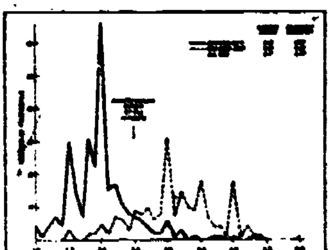

Fig. 3 Distribution of FY1981 peer-reviewed awards and declines by average panel rating.

Discussion

The above description is largely a mechanistic one of the step-by-step process by which OSRS proposals are peer reviewed. In practice, this process is a rather complex, interactive, and human one. All mail and panel reviewers bring to bear their own technical expertise, perspectives, values, and communicative skills. But they do so under significantly different circumstances. Mail reviewers judge an individual proposal in relative isolation and need have little concern for being challenged. By contrast, panelists make their judgments with more information at hand, including mail reviewer comments and some knowledge of available funds and of other proposals competing for these funds. Furthermore, their judgments are made in a forum where differing perspectives and values may well be challenged and where small group dynamics can be significant.

Clearly, attempting to evaluate quantitatively a process like this or assess its effectiveness is fraught with difficulties. Furthermore, it is important to recognize the subjective, substantive, and judgmental elements of the process in these attempts. A good example is the use of average mail review ratings in analyzing the NSF peer-review system. While in some cases an average rating does represent a consensus on the merit of a proposal, in many cases it does not. For example, one proposal with an average mail review rating of 'very good' might have two rather perfunctory excellents, a qualified very good, and one very well-considered and critical fair. Another proposal also with an average mail review of 'very good' might be rated as good by two reviewers who find the new methodology proposed is unproven and as excellent by two other reviewers, one of whom knows from experience that the approach will work and the other who feels the potential scientific payoff is worth the risk.

The significance of an average mail review rating under such circumstances, which occur fairly frequently, is clearly questionable. How frequently and how questionable are difficult to measure. One indication is provided by the numerical range between the highest and lowest mail review ratings of an individual proposal. For FY1981, 38% of all our peer-reviewed proposals had ranges of 2.0 or more in their individual sets of mail review ratings. In the most critical area of proposals with average mail review ratings between good and very good, this percentage was just over 60%. The substantive comments underlying large ranges in mail review ratings of individual proposals do affect the award/decline decisions on them. This is shown by success rates for proposals with different ranges. Again in the critical area of proposals having average mail review ratings from 2.0 through 3.0, the success ratio (awards over proposals peer reviewed by both mail and panel) was 54% for the 53 proposals having a

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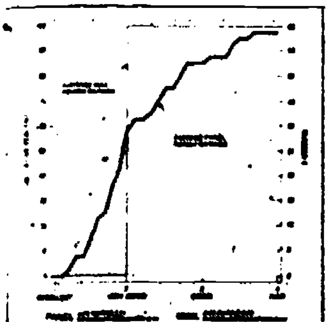

Fig. 4. Distribution of FY1981 panel-rated proposals that had average mail review of very good by average rating.

range of 3.0 in their mail review ratings. The success ratio was 50% for the 101 proposals having a range of 2.0 and 54% for the 70 proposals having a range of 1.0. These different success ratios, of course, reflect panel as well as mail reviewer advice on the proposals and suggest that panelists have some tendency to agree with the more critical mail reviewers.

Frequently, the average panel and average mail review ratings of individual proposals differ significantly. For FY1981, these rating differences were 1.0 or more for about 12% of the proposals and 0.5 or more for almost 45% of the proposals. Figure 4 illustrates the extent of average mail and panel rating differences for a selected subset of proposals. It shows a cumulative histogram of average panel ratings for the 62 proposals in FY1981 that had average mail review ratings of 2.0 and that were also rated by panels. If one considers the likely influence of different perspectives and evaluative circumstances on mail and panel reviewers, the observed rating differences on the whole seem quite understandable.

The Final Decisions

Throughout this entire process, the members of the program staff are clarifying their own views concerning proposals and are sifting and filtering the advice provided by mail and panel reviewers. By the end of a panel meeting, decisions for a majority of the proposals have become clear. For a sizeable minority, however, the members of the program staff go through a post-panel period of reflection and analysis. During this period they weigh the impacts of their potential decisions on the scientists involved and on the field itself. At the same time they must ensure that their award decisions will all fit within the very real limits of their program budgets. They also frequently consider a number of other factors (balance between fieldwork, laboratory studies, and data analysis; new versus established principal investigators; institutional health; and geographical distribution) that can become important in the close calls that have to be made and justified.

The decisions by program staff take the form of recommendations that must be approved by at least two higher levels within NSF. Retrospectively, samples of their award/decline decisions are reviewed by internal auditors and external oversight review groups for technical soundness and conformance to policy.

Notwithstanding all of the advice given both before and after the fact, it is fair to say that OSRS program staff play the most significant role in how these particular governmental decisions are made. They operate at the critical interface and provide the clearest window between academic research scientists and the government bureaucracy. They exchange advice with and are accountable to both. They are the heart of the OSRS peer review process.

Acknowledgments

I thank all of the OSRS program staff who, over the years, have helped clarify my view of our peer-review process and have diligently coded much of the proposal information contained in our data files. I especially thank Gail Williams, whose continuing efforts in building and editing our data files have helped make it possible to quantify some aspects of the process. Finally, I thank Peter Brewer, Don Heinrichs, Bruce Malfait, and Mike Reeve for their helpful reviews of a draft version of this article.

Robert E. Wall is Section Head, Ocean Sciences Research Section, National Science Foundation, Washington, D. C.

STATEMENT OF FERRIS WEBSTER, PROFESSOR OF OCEANOGRAPHY, UNIVERSITY OF DELAWARE

I am Ferris Webster, Professor of oceanography at the University of Delaware, and this year's elected chairman of the University-National Oceanographic Laboratory System (better known as UNOLS).

The University-National Oceanographic Laboratory System

UNOLS is a private organization of academic oceanographic institutions which operate oceanographic facilites. To paraphrase the objectives as set forth in the UNOLS charter: UNOLS is a national system that works with the funding agencies to assist in the effective coordinated use, assessment, and planning of oceanographic facilities for graduate-level research and educational programs. By optimizing Federal and other support for academic oceanography, UNOLS will thereby continue and enhance the excellence of this nation's oceanographic program.

Support for the operation of UNOLS is provided by the Federal agencies that support or use the academic oceanographic fleet. These are the National Science Foundation (NSF), the Office of Naval Research (ONR), the National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS), the Marine Mineral Service (MMS), and the

Department of Energy (DOE). The funding for UNOLS operations that is provided by this group of agencies is coordinated through the NSF.

Eighteen universities and research institutions are members of UNOLS, and another thirty-one are associate members. Meetings are held twice a year. Between meetings, business is carried out through an Executive Committee, an Advisory Council, and a number of specialized committees. A full-time Executive Secretary is located with the School of Oceanography of the University of Washington in Seattle.

Fleet Coordination

The ships and other facilities operated by UNOLS institutions have mainly been acquired though NSF and ONR. Of 26 research vessels in the UNOLS fleet, NSF holds title to 12, ONR to 7, and 7 have been acquired by other means, generally through state or institutional sources.

UNOLS members have been working with the funding agencies to improve and maintain effective use of the academic research fleet. NSF is the largest user of the Academic fleet, with the support by agency breaking down as:

NSF	60-70%
ONR	10-15%
NOAA, USGS, NMS, DOE	10-20%
Other	10%

The challenge in managing the fleet is to match the facilities and support available to the needs of the science program. The actual scheduling of the fleet is carried out by the individual operating institutions. This procedure maintains close ties between the ship operators and the scientific investigators. In general, the science is accomodated, with some competition by funded research programs to get the available ship time. If there is a problem, it's that the field may be underfunded, so that too high a percentage of good science proposals are rejected.

I am pleased to report that the cooperative scheduling of the UNOLS fleet has been working well. I want particularly to acknowledge the constructive help of the National Science Foundation in achieving this.

<u>The Current State of the UNOLS Fleet</u>

At the current time, the UNOLS Fleet is in relatively good shape. There is a good balance between science program needs and fleet capacity. The fleet is almost fully utilized.

Fleet usage has been increasing modestly over the last five years, though it is significantly below the levels of the previous five years. Fleet usage was 4,494 days in 1983 and is estimated to be 5,210 days in 1984. The projection for 1985 is 5,999 days. Note however, that the average ship usage over the five-year period from 1975 to 1979 was 6,056 days.

To put the present fleet funding situation in perspective, it may be worth recalling the history of the academic fleet. Over the last fifteen years, the national capability to work at sea from academic research vessels has dramatically decreased.

An analysis prepared by the UNOLS Advisory Council two years ago indicated that the academic research fleet shrank from 35 vessels in 1971 to 25 in 1982. The size of the research fleet was, however, merely a symptom of the general decline of the overall support of oceanographic research by all the Federal agencies. There has been a particularly strong decrease in funding of oceanographic research by ONR, which has failed to keep up with inflation to the extent that today's program is significantly smaller than it was in the late sixties.

Some increases in Federal funding for the fleet have occurred in the past two years, and there may this year be adequate resources to support the existing fleet.

Fleet Replacement

Within the next decade, UNOLS members and the Federal agencies will face a major challenge in coping with the aging of the academic fleet. The FOFCC Oceanographic Fleet Study Report notes that, using a 30-year lifespan for a research vessel, half of the UNOLS fleet should be retired by the end of the century. The problem is most severe with the larger vessels in the UNOLS fleet.

UNOLS has placed a high priority on dealing with the issue of aging of its research vessels, and has established a Fleet Replacement Committee to develop a plan for orderly replacement of the UNOLS fleet. We expect that the results will lead to recommendations to the funding agencies. The committee's work is coordinated with the Federal Oceanographic Fleet Coordinating Council (FOFCC) oceanographic fleet study, with UNOLS participation and staffing. In addition, the Fleet Replacement Committee is representing the UNOLS community in the Navy's program to develop characteristics for a new ship for the academic fleet.

A related issue is the composition, distribution, and management of the UNOLS fleet. A report to UNOLS on this subject was prepared by the UNOLS Advisory Council in 1982. In the two years since then, the situation regarding fleet usage and needs has changed. Some of the conclusions of the 1982 report relating to fleet composition are no longer applicable. The Advisory Council is preparing an update, which it plans to complete by May, 1985.

Future Issues

UNOLS is addressing issues of future importance to the academic research fleet.

The UNOLS Advisory Council is looking at new platform designs as part of its interest in orderly fleet replacement. Might new types of platforms (multi-hulls, semi-submersibles) be more effective than simple replacement of one conventional ship with another?

Oceanographic satellites, despite their promise, have not yet appeared on the scene. When they do, possibly towards the end of this decade, they may stimulate new means for worldwide oceanographic research. New programs being developed to understand global climate variability are examples of how these new tools might be exploited. There will surely be an impact on ship usage, though I am uncertain that the new global research perspective will mean that will will need fewer ships.

UNOLS is developing new procedure to improve the national planning for distant, expeditional research activities. The idea is to improve the use of ships in distant waters through early discussion of plans by scientists from all interested institutions. The first results are promising, and preliminary plans for coordinated distant-water research operations in 1986 and 1987 are taking shape.

To conclude, I am proud of UNOLS's solid accomplishments in what may be less glamorous areas than those discussed so far: establishing and maintaining standards for safety on all UNOLS ships; promoting the more effective use of shipboard scientific gear; ensuring that funded oceanographers from all U.S. institutions have access to the fleet; promoting communications between the ship-operating institutions and oceanographic research scientists; arranging for at-sea world-wide medical assistance to all UNOLS vessels. These effective steps in improving the use of the academic research fleet have justified the effort put in by many individuals to create UNOLS and to make it work.

STATEMENT OF TUDOR DAVIES, SPECIAL ASSISTANT OF THE ASSISTANT ADMINISTRATOR FOR WATER, U.S. ENVIRONMENTAL PROTECTION AGENCY

Mr. Chairman and Members of the Subcommittee:

Marine research within EPA is conducted to provide information and a scientific basis for our regulatory activities governing ocean disposal. The Agency has often testified before this Subcommittee on our implementation of the Marine Protection, Research, and Sanctuaries Act, that is, the regulation of ocean dumping of wastes. We also have responsibility under the Clean Water Act for regulating all point source discharges to waters of the U.S., including estuaries and the territorial seas. These discharges must be permitted in accordance with National Pollution Discharge Elimination System requirements under Sections 301 and 402 of that Act. In addition, all discharges to the territorial seas, contiguous zone and open oceans must meet the criteria and guidelines under Section 403(c) of the Clean Water Act. Under the auspices of these two Acts, the EPA has the major responsibility for regulating the disposal of industrial and municipal wastes in the oceans. EPA is also responsible for designating dump-sites and providing criteria for evaluating permit applications to the Corps of Engineers for ocean dumping of dredged materials.

In structuring a research program to support regulatory activities for waste disposal in the oceans, we focused on the need to develop quantitative and predictive methods for determining impacts on ocean ecosystems. The framework for this approach is the hazard assessment procedures. These procedures are based on information required by the ocean disposal permit program for site characterization; waste characterization and quantification; pre-disposal assessment; and monitoring. This concept is generic in nature and may be applied to any type of waste and any particular disposal site.

The initial step in an ocean disposal decision is characterization and designation of a disposal site. In charaterizing sites, EPA compares the characteristics of a proposed site with environmental criteria specified in EPA's regulations, including the types and quantities of wastes proposed for disposal at the site. Site characterstics which are identified include depth, type of bottom, currents, and fisheries. Waste characterization only involves differentiation of wastes on the basis of their sources (e.g., dredged materials, sewage sludge, and industrial wastes), since site characterization is a pre-permit activity. A workshop was held in February 1983 for the development of a scientific protocol for ocean dumpsite designation. This protocol is now under consideration by EPA and the Corps of Engineers for use in their permitting programs.

After a site has been designated for disposal, a waste characterization process is conducted for the specific waste in each permit application. Waste materials are characterized by those physical properties which determine its fate and transport in the environment, and by those chemical properties related to toxicity, residue formation, and biostimulation. The results of waste characterization provide the basis for an initial evaluation of the suitability of a candidate waste for disposal at a designated site. Research is currently underway to develop or revise procedures to better enable wastes to be evaluated. This effort will result in a user manual for evaluating wastes proposed for ocean disposal.

A key step in permitting waste disposal is determination of hazards to the environment. A process we call hazard assessment provides the necessary data and interpretive procedures for estimating the probability of harm to the aquatic environment. The principal components in this process are exposure assessment and effects assessment. Exposure assessment consists of estimating the duration and intensity of contaminant exposure for potentially impacted biological communities. Examples of exposure assessment research include studies on the effect of current directions on ocean outfall mixing rates and the development of a three-dimensional analytical model for predicting transport and fate of ocean dumped contaminants at the 106-mile dumpsite. Effects assessment consists of estimating the responses of impacted biological communities in terms of toxicity and tissue residues. Research is being conducted on the effects of pollutant interactions on sediment toxicity and on multi-species flow-through bioassay to predict ecological impacts of dredged material disposal. Research on the use of a thermodynamic model for predicting the maximum contaminant bioaccumulation from sediments and sewage sludge is very promising. Hazard assessments are intended to be sequentially tiered, that is, information from each level of testing is evaluated to determine if additional information is necessary to arrive at a disposal decision with a prescribed level of confidence. Generally, simple tests are followed by more complex tests. Tiered hazard assessment procedures are currently under development.

If a decision is made to issue an ocean dumping permit, or a 301(h) waiver is granted, monitoring activities are initiated, pre- and post-disposal, for the purpose of verifying that the predicted effect has in fact occurred. The scope of these activities is defined by the conditions of the

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particular permit. Currently, emphasis is being given to the use of caged shellfish for monitoring biological effects in coastal environments and shallow dumpsites.

EPA ocean disposal research is closely coordinated with other agencies to eliminate duplication of effort and assure the best use of available resources. For example, EPA is participating in the aquatic portion of the U.S. Army Corps of Engineers Field Verification Program (FVP). The dredge site for the FVP is Black Rock Harbor in Bridgeport, Connecticut. The overall objective of the aquatic portion of the FVP is to use the dredged material disposal as a case study for implementing the hazard assessment strategy. The major components of the study include waste characterization, exposure assessment, effects assessment, and monitoring. Site characterization, per se, is not being conducted because the disposal site has already been designated. The disposal of dredged material started in the spring 1983. The study will continue for a period of three years after disposal.

EPA has also worked closely with the National Oceanic and Atmospheric Administration (NOAA) in the preparation of site characterization reports related to designation of the 106-mile ocean dumping site. EPA and the National Marine Fisheries Service (NMFS) collaborated on the update of the 106-mile site characterization report and EPA contributed to the NOAA/NMFS physical oceanography report on the area.

We hope this synopsis of the Agency's marine research conveys to the Subcommittee our approach to supporting our ocean disposal statutory requirements and our commitment to interagency coordination.

For your further information, EPA is in the process of consolidating its national program responsibilities for oceans and coastal waters into the Office of Marine and Estuarine Protection (OMEP) to be located in the Office of Water. The purpose of this organizational consolidation is to ensure the provision of timely and consistent national direction, support, and overview for EPA's marine and estuarine regulatory activities under the Clean Water Act (CWA), Marine Protection, Research, and Sanctuaries Act (MPRSA) and related environmental statutes.

Specifically, OMEP will be responsible for providing policies, national program direction, support, and overview for:

- the municipal marine discharge variance program under Section 301(h) of the CWA,
- regulation of ocean discharges... including discharges related to ocean minerals and energy development and production activities...under Section 403(c) of the CWA, and
- site designation and permit issuance for ocean disposal under the MPRSA, as well as EPA's commitments to the London Dumping Convention (LDC).

OMEP will also be responsible for providing national direction, support, and overview for EPA's Estuarine Initiative... a systematic, cooperative Federal, State, and local approach for improving, maintaining, or enhancing the nation's estuaries and coastal embayments. Finally, OMEP will be closely coordinating the marine and estuarine regulatory activities under the CWA and MPRSA with related activities under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA) and the Safe Drinking Water Act (SDWA).

OMEP will be administering its responsibilities in close coordination with EPA's Office of Research and Development because of the substantial need for additional research on many of the marine and estuarine environmental protection technical and scientific issues facing us today. OMEP will be coordinating and cooperating with other Federal agencies such as the:

- National Oceanic and Atmospheric Administration on environmental monitoring and natural resource (primarily fishery) issues and programs,
- Corps of Engineers on ocean disposal of dredged materials,
- U.S. Coast Guard on ocean disposal compliance monitoring and surveillance activities, and
- Minerals Management Service of the Department of the Interior on offshore ocean mining and oil and gas lease sale issues.

And, OMEP will be reporting to Congress regularly on the status of our marine and estuarine programs... annually, for example, on administration of the MPRSA and LDC.

We welcome the Subcommittee's interest in our marine activities and look forward to working with the Members on ways of enhancing cooperation and collaboration with other ocean-related agencies.

Mr. STUDDS. I would like to begin by asking each of you to identify yourself and the office for which you work and to state, very briefly, the nature and scope of the responsibility which your agency has for marine scientific research.

Mr. Wolff, do you want to go first?

STATEMENTS OF PAUL M. WOLFF, ASSISTANT ADMINISTRATOR, NOAA, DEPARTMENT OF COMMERCE; ROBERT S. WINOKUR, ASSOCIATE TECHNICAL DIRECTOR FOR OCEAN SCIENCE AND INTERNATIONAL PROGRAMS, OFFICE OF NAVAL RESEARCH, DEPARTMENT OF THE NAVY; DR. M. GRANT GROSS, DIRECTOR, OCEAN SCIENCES DIVISION, NATIONAL SCIENCE FOUNDATION; DR. FERRIS WEBSTER, PROFESSOR OF OCEANOGRAPHY, UNIVRESITY OF DELAWARE; AND DR. TUDOR DAVIES, SPECIAL ASSISTANT TO THE ASSISTANT ADMINISTRATOR FOR WATER, U.S. ENVIRONMENTAL PROTECTION AGENCY

Mr. WOLFF. I am Assistant Administrator of NOAA for Ocean Services and Coastal Zone Management. My office is not directly connected with research. We are a service organization.

Mr. STUDDS. Mr. Winokur.

Mr. WINOKUR. I am the Associate Technical Director for Ocean Science and International Programs at the Office of Naval Research. In addition, I also serve as the Executive Secretary for the Federal Oceanographic Fleet Coordination Council, which is an interagency ship coordinating council.

The Office of Naval Research, under the Director of the Chief of Naval Research, is responsible for all basic research within the Navy. As a component of that, we have a significant program in what we refer to as ocean science in the Navy.

Mr. STUDDS. Dr. Gross.

Dr. GROSS. I am the Director of the Division of Ocean Sciences for the National Science Foundation.

We support research and facilities necessary for the research at the academic institutions. We provide on the order of 70 percent of the moneys going to the U.S. academic science community for work in the oceans.

Mr. STUDDS. Dr. Webster.

Dr. WEBSTER. Thank you, Mr. Chairman.

I am not a Federal employee, nor am I representing a Federal organization, contrary to your introduction. I am a professor of oceanography at the University of Delaware, and I am this year's elected chairman of the University-National Oceanographic Laboratory System, which is a private organization of academic oceanographic institutions that operate facilities.

Mr. STUDDS. It is not necessarily bad not to be a Federal employee. [Laughter.]

Dr. WEBSTER. I understand that. I have tried it both ways, Mr. Chairman.

Mr. STUDDS. Dr. Davies.

Dr. DAVIES. I am currently a special assistant to the Assistant Administrator for Water. Beginning very shortly, I will be the Director of the Office of Marine and Estuarine Protection in the Office of Water.

Mr. STUDDS. In EPA.

Dr. DAVIES. In EPA.

We are collecting together the various marine programs that have existed in the Office of Water but have been in separate offices. Our responsibilities are for implementing the EPA's role in the Marine Protection Research and Sanctuaries Act, the so-called Ocean Dumping Act, and parts of the Clean Water Act whcih relate to ocean outfalls, and various ocean-water-quality issues.

I have sitting behind me Dr. Doug Lipka from the Office of Research and Development within EPA. The Research and Development Office has responsibility for ocean-disposal research, toxics research, pesticides research, et cetera, within EPA.

Having heard Jerry Schubel this morning, I can understand why you staff asked me to sit here this afternoon.

Mr. STUDDS. I want to thank you all for your willingness to forgo the opportunity for an oral presentation of your statements. Maybe it strikes you as a pleasant change in the normal procedure, but in any event, it is absolutely necessary, as you can clearly see, given the timing, and we very much appreciate it.

We will go directly to questions.

Mr. Winokur, you are the Chairman of the Federal Oceanographic Fleet Coordination Council, an utterly unpronouncible acronym. The 1982 report of the Federal oceanographic fleet found that:

> The long-term trend in the state of the Federal fleet shows continuing overall decline forced by high costs of operations, Government budget economies, and a lack of action to replace aging vessels. The Federal fleet's capability to conduct blue water oceanography has been significantly reduced. This unfortunately is happening at a time when the nation is moving ahead on economic, energy, and national security policies which require increased ocean exploration and study.

Has a plan been developed by your office or by any other agency that would match future oceanographic research needs to planned new procurements and renovations of research vessels?

Mr. WINOKUR. Yes.

If I may start off by just one minor correction, Rear Admiral Mooney, Chief of Naval Research, is the Chairman of the Council. I might point out that the chairmanship is rotated among NOAA, Navy, and NSF.

Mr. STUDDS. Fine. I appreciate the correction.

Mr. WINOKUR. I am serving as the executive secretary. I have also served as the chairman of the coordination board of the Council. We agree, by the way, that the Council name is difficult to deal with, so we refer to it as FOFCC.

In that capacity as chairman of a working group, I directed a study to look at, if you will, the health of the Federal research fleet.

I would like to very briefly point out that the Council was, in fact, formed in 1980 in recognition of the need to coordinate the management of the research vessels operated by the Federal agencies. I believe, since that time, the Council has been a very effective coordinating mechanism.

We have recently completed a study by the Council to look at the health and welfare, I guess is the simplest way to look at it, of the Federal ship assets that we have. One of the findings of the Council study and one of the major concerns that has been brought out in the previous panel is the age of the Federal fleet.

The Federal fleet currently has a median age of about 17 years, which means that in the 1990's, given the current composition of the fleet, over 50 percent of the fleet will age more or less concurrently. In recognition of that fact, the Council has recently established a working group on ship replacement. I also serve as the chairman of that working group.

The agencies have already met together to discuss a strategy and to develop a plan for future replacement of this national asset. Currently, the Federal fleet comprises a little over 60 ships.

The study that you referred to and that I have mentioned was conducted in recognition of the fact that there were problems with the Federal fleet. Funding was on a decline, and agencies were forced to lay up ships.

One of our findings of the study is that we think things have stabilized. Funding has increased over the last year or so. There has been no further decline in the fleet. We see and we project future requirements that justify the current composition of the fleet.

So, I believe that the Council, acting as an interagency coordinating body, is dealing with the problems facing the fleet. The main problem, at this point, that we are concerned with is ship replacement. We are working and developing a plan to address that collectively.

When I refer to the Federal fleet, I mean not only the ships operated by the Federal agencies, but those ships that are operated by academic institutions but which are funded or owned by Federal agencies.

Mr. STUDDS. OK.

I would like Mr. Wolff and Dr. Gross each to comment on the status of plans for replacing and/or upgrading the research vessels operated by your agency or under your control. First, Mr. Wolff.

Mr. WOLFF. NOAA operates 21 ships at the present time, and we have one ship which is in laid up condition, although semiready to be put back into operation.

These vessels are in extraordinarily good condition so far as hull and operating machinery are concerned. When we consider our requirements for vessels, our class I and class II vessels are still state-of-the-art. There has been no new development in ship design which has reached the point where NOAA is ready to recommend the acquisition of further ships.

The equipment on the vessels for taking scientific measurements and the computers to process that information are sorely outdated. We have identified that it will cost between $2.5 and $3 million per ship to bring our fleet into full capability condition, and that is our first priority. Since the cost of a new vessel to replace one of our class I ships is something on the order of $30 million, I think the use of the $30 million to upgrade 10 vessels is a much more cost-effective use of the money for the near term. Considering the state of the vessels and the effort that has been put into their upkeep and the price that the NOAA Corps officers have in keeping them in first class condition, they will run until the year 2000 without difficulty.

Mr. STUDDS. I assume your reference was to one of the largest of them, the *Oceanographer* presently in mothballs in Seattle?

Mr. WOLFF. Yes, sir. It is a matter of highest priority to NOAA to get that vessel back underway because we have more requirements for class I vessels than we have shiptime at the moment.

Mr. STUDDS. Is it as high a priority for OMB as it is for NOAA?

Mr. WOLFF. I have met with OMB on this subject, and I continue my best efforts to convince them of this.

Mr. STUDDS. Let me put it this way, could it be used efficiently if it were reactivated?

Mr. WOLFF. Yes, sir.

Mr. STUDDS. OK. Thank you. I appreciate the situation you are in.

What is the status of the vessels under the control of the NSF?

Dr. GROSS. Let me respond on two different points. First, the Foundation is directly involved in the operation of two vessels. One of them, the ocean drilling vessel, the SEDCO-BP-471, recently chartered, has just entered the shipyard for conversion as a modern ocean drilling vessel. It will be available for shakedown cruises in December and for scientific drilling in January. So, we believe that this is a state-of-the-art capacity.

In the Antarctic region, the Foundation has a lease-purchase arrangement through its contractor for the *Polar Duke*, a new vessel about 2 years old, 219 feet long, which greatly improves our Nation's research capabilities in high latitude.

Second, we share with the other agencies the support of the UNOLS fleet. Dr. Webster may wish to comment on the UNOLS activities to assist us in defining the scientific characteristics. Since these determine what should be the appropriate mix of the fleet, to take care of the university-community's scientific requirements over the next 10 to 20 years. Basically, we are now awaiting the report from UNOLS. Once we have that, we will be working with the other agencies, probably in conjunction with FOFCC, and will then prepare our agency response. At the moment, we do not have the reports available.

Mr. STUDDS. Dr. Webster, would you like to add anything with respect to the likelihood or the unlikelihood of having an adequate oceanographic research fleet over the next 5 to 15 years?

Dr. WEBSTER. I would like to second what Dr. Winokur said. The comments he made about the aging of the fleet between now and the end of the century apply equally to the research vessels that are operated by the Nation's universities and oceanographic institutions. They, too, are suffering from the same age problem.

As Dr. Gross has said, we are developing a plan. We have set a highest priority for a fleet replacement committee to work with the Federal agencies and with the academic institutions to develop the characteristics of ship replacement and/or refurbishing between now and the end of the century. That is going to be an ongoing activity.

In response to your question to me, I am optimistic that we will have the adequate fleet to meet the oceanographic research needs in the oceanographic institutions, at least to meet the level which is provided by the funding available.

Mr. STUDDS. Dr. Gross, earlier we heard Dr. Heath of the University of Washington testify in support of block funding to oceanographic institutions to rebuild the research infrastructure which both he and Dr. Baker described as inadequate and decaying.

Do you share the view that oceanographic institutions require this kind of help? Do you think it would be in the national interest to provide it, and do you think you can persuade OMB to endorse it?

Dr. GROSS. I am not sure where to start. First, we share Dr. Ross' concern that the infrastructure, which includes not only the ships but the equipment aboard the ships and the laboratories, has not received the support and the attention that I would personally like to have seen. We feel that on the ships we have done a reasonably successful job in arresting a deteriorating situation and that we can now look forward to a fleet which is capable of efficient, effective operation over the next 5 to 10 years. We have also made progress on the equipment aboard the ships.

Laboratory equipment is a large-scale problem. I am not sure that any of us have a full grasp of exactly how large it is. We heard an estimate on the order, I think, of $30 million a year to handle that. To be quite candid, we in the Foundation right now do not have that in our budget. And it seems unlikely that we can divert that amount of money out of our present research support without causing other great problems in the university community.

The prospect for an additional $30 million in our budget is something which we would have a great deal of discussion about, both within the agency and with OMB. I wouldn't want to predict our success on that.

Mr. STUDDS. Dr. Davies, you make reference in your written statement to EPA's estuarine initiative, a "systematic, cooperative Federal, State, and local approach for improving, maintaining, or enhancing the nation's estuaries and embayments." That sounds wonderful. Could you please describe it, and feel perfectly free to use Buzzards Bay as an example of how it might work. [Laughter.]

Dr. DAVIES. As you know, and you were probably very involved with the appropriation that was given to EPA for fiscal year 1985, we are concerned within EPA that we are seeing a decline in the number of estuaries around the country in terms of biological resources. We are seeing expanded development on these estuaries, and we have seen our regional offices, State offices, public and scientific communities comment on this decline and the need to take perhaps an alternative approach to the one we are taking at the present time.

As you know, we have the Clean Water Act, which largely controls our ability to regulate sources coming into these estuaries. Our major focus is to develop some basic science on the estuaries themselves, the status of the resource, an understanding of the scources of pollution, nutrients, toxics, et cetera, coming into the estuaries. We want to get a better definition of how we can control those sources as well as alternatives available to control.

Dr. Schubel, in his discussion earlier, I think, was referring to some previous Federal studies in which perhaps the scientific community was involved as a contractor rather than as a designer. I think I would just like to reflect on that for a moment, with your permission.

Mr. STUDDS. Please do.

Dr. DAVIES. Speaking as somebody who made his living as a research scientist for a while, and I am now in the regulatory business with EPA, the role of scientists with regard to scientific information, particularly in something like regulating sources and dealing with public policy on priorities for source regulation, is a difficult one. The scientific need, both in myself and in the scientific community, is that we need to know a great deal about cause and effect.

However, in the world of regulation, you are looking at dealing with the existing science or perhaps a little more than the existing science, looking at your alternatives and making a best judgment at that point, and perhaps then creating something like a political will to take some action.

We have seen, in Chesapeake Bay, and we saw to some extent in the Great Lakes, that there was a public perception, and a political perception, that something was wrong and something needed to be done. We made the best judgment in terms of a regulatory strategy. Perhaps the total science was not fully understood, but we moved forward and I think we have accomplished something.

That did not mean that the regulatory agencies went to the scientific community and asked them what science I needed to do. The scientific part is, I would say, only a portion of the process that we go through. Part of the process is developing the coordinating mechanisms to use the available legislative and regulatory tools that we have and the science is only a part of that.

So, when we come to look at Long Island Sound, Narragansett Bay, Buzzards Bay, and Puget Sound, which was inserted into the appropriation, we think it is very important that the State regulatory agencies, the public, and the scientists be involved in developing a concept of the problem as it exists in those areas and an approach to the solution. Otherwise, we will have, perhaps, a scientific document that will be poorly communicated, and hard to understand. Perhaps we will have much better science, but we will have little ability to have built an institution to do something about those problems.

Mr. STUDDS. Thank you.

Mr. Wolff, what role, if any, will NOAA play in this program?

Mr. WOLFF. We are engaged in a program we call Status and Trends, which is monitoring the state of the pollution around the shores of the United States. This involves several sections of NOAA. Dr. Ehler is in charge and works very closely with Dr. Davies in EPA. They are making considerable progress and have a draft of a plan to monitor the pollution levels on a 6-month or a 1-year basis all around the coast of the United States so we can tell if the level of pollution from any particular pollutant is increasing or decreasing.

I think that establishing this long-term baseline from which we will be able to detect changes is very important. In addition, they are producing atlases of different kinds of effects which get into combinations of variables involving fisheries, in particular, both shellfish and finfish. These are proving to be of value not only to

EPA and to the agencies within NOAA, but to the fishermen themselves and to the public. So, I think we have a cooperative program in being with EPA which has increased markedly in the short time I have been with NOS.

Mr. STUDDS. Thank you.

Mrs. Schneider, my apologies. I went over time.

Mrs. SCHNEIDER. Mr. Winokur, I would be interested in knowing about the Navy-owned multichannel sonar devices which I am aware having been doing some very valuable and extremely cost effective work, particularly in the EEZ. I was wondering what plans the Navy might have to share that data that is being collected with some of the academic and Federal oceanographic institutions.

Mr. WINOKUR. The Navy has collected data in portions of the U.S. EEZ. These data are generally classified and are not released as unclassified. The data can be made available to properly cleared personnel who have a demonstrated need to know and who can protect the classified data.

Mrs. SCHNEIDER. Who determines that this research data ought to be classified? Is it the Secretary of the Navy himself or whom?

Mr. WINOKUR. These are not research data. These data are collected as part of the Navy's charting program.

Mrs. SCHNEIDER. But who determines that it should be classified?

Mr. WINOKUR. Within the Office of the Chief of Naval Operations.

Mrs. SCHNEIDER. So, all of the data that is being collected now is all classified?

Mr. WINOKUR. Well, not all data that the Navy collects is classified.

Mrs. SCHNEIDER. No, I am referring specifically to this EEZ data that is being collected.

Mr. WINOKUR. Yes, the data that ~~are~~ collected as part of our charting program that lie within the EEZ are classified.

Mrs. SCHNEIDER. Why?

Mr. WINOKUR. We can provide an answer for that for the record. I do have with me Captain Larry Wortzel from the Department of Defense who can also contribute to the answer.

Mrs. SCHNEIDER. I am curious, because if I understand correctly, NOAA is also doing some charting of the EEZ area, and, if I understand correctly, the data that they are collecting is not classified. Am I correct?

Mr. WINOKUR. I can't comment on the NOAA data, per se, since we are not involved with that. There are interagency discussions relative to that.

Mrs. SCHNEIDER. Mr. Wolff, the data that you are collecting at NOAA on the EEZ, that is not classified, is it?

Mr. WOLFF. That is right; it is not classified. As a result of the declaration of the EEZ, Dr. Byrne and Dr. Schneider in NOAA assigned me the responsibility to begin to use our sea-beam sounding system to develop a plan for a systematic mapping of the EEZ. So, I produced some NASA-type gee-whiz charts. I am holding one up here, which has the contours of the bottom on it. It is altogether spectacular geology.

As soon as I saw these, I became enthusiastic about the program, even without Dr. Schneider and Dr. Byrne's efficient urging. So, we have already processed a few sheets like this. We intend to map the entire EEZ from the 150 meter depth out to the edge of the shelf or 200 miles, whichever occurs first. This will have enormous impact on a number of U.S. economic activities, including minerals and oil and fisheries.

The fish are particularly sensitive out to the 2,000 foot depth to these kinds of contours. We were quite surprised, since this instrumentation is 10 years old and number of foreign ships are known to have it, that there was any question about the classification, but we are considering this in a working group with the Department of Defense now to see if there is a compromise position which meets our requirements and the DOD requirements.

However, the NOAA position is that the basic suite of geophysical observations in the EEZ are unclassified and should be freely passed about, and we see no arguments that convince us that this is not a valid position.

Mrs. SCHNEIDER. Does NOAA have a mechanism whereby they provide this information to the academic community upon request?

Mr. WOLFF. This is a joint program with the Department of Interior, and both of our files will be available to any U.S. source.

Mrs. SCHNEIDER. Mr. Winokur, I have a conflict in my own mind. Am I to understand that we have two Federal agencies that are duplicating efforts, Navy and NOAA? And, the second question is, are they both doing the same thing and one is deciding to classify the data that is collected and the other agency deciding not to classify it, and is that not a form of inconsistency in our Government policy?

Mr. WINOKUR. The Navy charting program has been a longstanding one, going on for many, many years before NOAA got a responsibility for charting in the EEZ. I don't think there is duplication of effort, as far as I can see.

On the other hand, there are concerns that have been raised, and there is an interagency group that is discussing these concerns.

Mrs. SCHNEIDER. And then insofar as the classification is concerned, one agency classifying and the other one not?

Mr. WINOKUR. I can provide an answer for that for the record, but there are legitimate concerns.

Mrs. SCHNEIDER. I would very much appreciate that, especially if you are both referring to the identical data that is being collected, but we will leave that for another time.

Mr. WINOKUR. I don't think we are referring to precisely the identical data. It is similar data. I am unable to comment on the areas of overlap, but we will provide an answer for the record. If you would like further discussion, as I say, I have someone here from the Department of Defense who can comment on that.

Mrs. SCHNEIDER. Well, if you could provide that to us at a later time, that would be appreciated.

[Material to be supplied may be found on p. 162.]

Mrs. SCHNEIDER. Mr. Wolff, in the mapping and the charting in the EEZ, how does NOAA share their information? You mentioned that you distribute the information, and I am wondering if you could elaborate a little bit on the mechanism of both coordination and information generation with the Navy and NASA in both gathering and processing all of that data.

Mr. WOLFF. We have the legislative responsibility for charting for navigation in U.S. waters. The Defense Mapping Agency has it for the rest of the world. We routinely do work for them and provide them with data in the standard, single-beam bathymetry style which is usually reduced to chart work sheets.

The state-of-the-art for bathymetry, however, is a digital data base which is stored in a computer and then can be accessed by any qualified user. So, the date which we are taking with Sea-Beam is being put into a digital data base, and this will be shared immediately with the Department of the Interior and then will be shared with the Defense Mapping Agency, of course. Our old data bases are being converted to digitial data bases as fast as possible. So our operation essentially is unclassified and everyone has free access to it. Then, we publish the charts which are used by mariners and are sold through our distribution system.

Mrs. SCHNEIDER. OK. Thank you.

One final question to you, Mr. Wolff, having to do with the National Ocean Pollution Planning Act, are you satisfied with the level of interagency planning or coordination that is taking place now?

Mr. WOLFF. I am rarely satisfied with anything in my responsibility. We are working hard to improve it. There are considerable coordinating mechanisms in place, and our relations with EPA are improving daily, so that I think that is one of our better areas.

Mrs. SCHNEIDER. OK.

Dr. Webster, seeing as how the University of Delaware has a particular place in my heart, I can't sign off without asking you at least one question.

So, I am curious to know, from your perspective as the National Oceanographic Laboratory System representative here, do you find that oceanographic research, data collection, and communications, both within the agencies, in other words, interagency, and communications between the agencies and the academic community are improving or degenerating?

Dr. WEBSTER. That is a difficult question. I think it is improving, mainly because our means of communication are improving.

Beneath it all, though, I think the issue you raised with the first panel about prioritizing and consensus, suffers because our community feeling of shared objectives is deteriorating somewhat. I think part of it is mechanical rather than real. Listening to the first panel, I got the clear feeling that many of them were saying the same thing in different ways. You were trying to get them to say what is more important, blue-water research or estuarine research. Both the blue-water people and the estuarine people were saying the same thing, namely that there needed to be an improvement in our national quality of freedom of research, and that there needed to be far more emphasis on the basic processes, even in Federal programs which are applied.

We have heard that addressed in different words from different people. What concerns me is that the community of agencies and the scientists and users and so forth are having trouble understanding that we do have certain common objectives, in spite of the improvement in electronic communication.

Mrs. SCHNEIDER. Thank you.

It is no accident that we have seen the budgets for the various marine programs and oceanographic programs, unfortunately, becoming smaller and smaller. I think that, unfortunately, that does have something to do with the lack of advocates and the lack of communications with the Congress and the decisionmakers who have their hands on the purse strings.

Certainly, as a special interest, I would say that the academic community has not been terribly vocal or communicative in asserting the priorities, the national interest, and the specific R&D needs of the oceanographic community. It seems to me that if we could have more of a unified voice in your communication with us, your interest might be more sufficiently accommodated.

Thank you, Mr. Chairman.

Mr. STUDDS. Thank you.

Gentlemen, I would like to pursue a little bit a line of questioning that Mrs. Schneider was pursuing in her gentle fashion, perhaps even too gently or perhaps my mind at this time of day is not grasping the subtleties of your response, and that is on the subject of the possibility of certain data being classified.

If you will forgive the elementary nature of my questions, I thought I understood who had responsibility for doing what kind of charting, but I want to make sure I have this correctly in the simplest way. My understanding to date was that the charting of U.S. territorial waters was traditionally the responsibility of the Geodetic Survey or the USGS now. Is that correct?

Concurrently, my understanding was that the charting of non-U.S. waters was the responsibility traditionally primarily of the Defense Mapping Agency. Am I right or wrong or both?

Mr. WOLFF. The latter is true, but NOAA has responsibility for the charting of U.S. territorial waters for purposes of navigation.

Mr. STUDDS. NOAA does?

Mr. WOLFF. Yes, sir; this responsibility stems from the old Coast and Geodetic Survey that was brought into NOAA. The National Ocean Service, which includes the former NOAA National Ocean Survey, now has this responsibility.

Mr. STUDDS. I see. Does USGS have any responsibility in that regard?

Mr. WOLFF. They map the land, essentially.

Mr. STUDDS. The land.

Mr. WOLFF. They also produce charts which go out to the ocean, but it is based on data we furnished them. We have had this responsibility since 1806.

Mr. STUDDS. I understand; we have been through that one. That is for U.S. territorial waters, right?

Mr. WOLFF. Yes, sir.

Mr. STUDDS. OK.

Now, am I also correct, Mr. Winokur, that traditionally, at least until recently, the chartmaking responsibilities for other than U.S. waters have been in the hands of the Defense Mapping Agency?

Mr. WINOKUR. I believe that is correct. It is not an area of my expertise, and I have someone here who could comment on that more directly if you like.

Mr. STUDDS. OK, but let me ask the rest of the question. Mrs. Schneider was getting at what I understand is going to happen now with regard to cooperative programs for surveying the bottom contours, bathymetric surveying of the EEZ or the 200-mile contiguous zone. Who will be responsible for that?

Mr. WINOKUR. It is my understanding that within the context of the EEZ charting, that responsibility belongs to NOAA and, I guess, in some cooperative way, with the Department of the Interior.

Mr. STUDDS. Is that NOAA's understanding?

Mr. WOLFF. Yes, sir. The USGS is responsible for the mineral mapping, and we are mapping for navigation, but we coordinate. We have a memorandum of understanding on the subject.

Mr. STUDDS. Now, in your statement, Mr. Wolff, I believe, you say that NOAA and the Defense Mapping Agency are currently negotiating over the question of whether EEZ bathymetric data will be classified. What does the Defense Mapping Agency have to do with that if you are gathering the data?

Mr. WOLFF. They brought it forward as a national security interest.

Mr. STUDDS. But it is your data; you are doing the gathering, right?

Mr. WOLFF. Yes, sir.

Mr. STUDDS. Now, let me go at this another way. Dr. Wolff, you say that NOAA and the USGS have initiated a multiyear cooperative program for bathymetric surveying of the 200-mile continguous zone, the EEZ. Is there anything particularly startling or distinctive about the nature of the data you will be developing or is this the type of information that NOAA has routinely developed for coastal areas through the Coastal and Geodetic Survey?

Mr. WOLFF. We have done little snippets before, sir, but this time we are going to do it systematically to produce the first maps of the whole area. In addition, the Department of Interior has employed a system called Gloria which is a side-looking sonar. That type of mapping produces some additional geological information. Our plan is to overlay the two.

It is also our plan, as was recommended by our peer advisory group from industry and academia which reviewed this program 3 months ago, to include magnetics and a full suite of geophysical observations, including the first two subbottom horizons. When we put all this together, we will have a map for the first time for this new U.S. territory which will have a multitude of uses. It did not occur to us, when we were planning, that there could be anything classified about it, because it is fundamental mapmaking. When you acquire a new territory, you map it, and it has such enormous applications in mineral exploration and particularly in fisheries, since the location, habitats, and where you can catch the fish is definitely located in the first 2,000 feet of this topography which is available for the first time. So, we had no idea there was any national-security issue involved, and we were quite surprised when it was raised.

Mr. STUDDS. What kind of national-security issue might be involved? I could see how one fisherman might like to get it and not let others see it, but you say when you first looked at it, it didn't occur to you there could be a national-security question. What national-security questions have occurred to you recently?

Mr. WOLFF. Oh, they haven't occurred to me; that is the DOD's position. [Laughter.]

Mr. STUDDS. I see.

Mr. Winokur, perhaps you could elaborate on that, given as how you work over there.

Mr. WINOKUR. If I may, Mr. Chairman, I would turn the floor over to Captain Wortzel who represents the Department of Defense on this issue.

Mr. STUDDS. Certainly.

Captain, would you please identify yourself for the reporter?

STATEMENT OF CAPT. LARRY WORTZEL, OFFICE OF THE DEPUTY UNDER SECRETARY OF DEFENSE FOR POLICY

Captain WORTZEL. Mr. Chairman, I am Capt. Larry Wortzel, an Army officer who is detailed to the Office of the Deputy Under Secretary of Defense for Policy. At the same time, I act as a representative of the National Operations Security Advisory Committee, called NOAC, which is a Committee of the Interagency Group, Countermeasures, an interagency group that is part of the Senior Interagency Group, Intelligence.

Mr. STUDDS. You ought to have a ribbon for remembering your assignment.

Captain WORTZEL. I do have a hard time remembering.

In any case, NOAC provides advice and recommendations to the senior interagency group intelligence on national security concerns and issues with national security implications in an intergovernmental forum. As, I think you and Mrs. Schneider have correctly observed, there may in fact be not so much an overlap in Government operations, but the operations of one department of the Federal Government may have an impact and have an effect on the operations of another department of the Federal Government.

Mr. STUDDS. My question was—you have just heard Dr. Wolff speaking for NOAA say that it was somewhat of a surprise to him that someone raised questions of possible national-security implications with respect to this very traditional kind of fundamental scientific data. What was it that you surprised him with by way of national security considerations?

Captain WORTZEL. The Chief of Naval Operations, in fact, raised the issue. As the mapping, charting, and geodesy manager for the Department of Defense, the Defense Mapping Agency has been able to make a contribution in a technical sense. We can supply for the record detailed accounts of the positions of——

Mr. STUDDS. How about a simple, English, general summary of some of the kinds of considerations?

Captain WORTZEL. Because of the data's high resolution and comprehensive nature, it could put the operating forces of the U.S. Navy at hazard and aid a potential enemy. Detailed data like that could provide assistance to a potential enemy in the conduct of naval warfare.

Mr. STUDDS. The bathymetric data in question seems to me, tell me if I am off base, to be very fundamental scientific data about the character of the Earth's surface. I can't imagine that it is considered for classification.

Isn't there a long tradition of making basic geophysical data available to the public?

Captain WORTZEL. Sir, I am neither an oceanographer nor a cartographer.

Mr. STUDDS. That must be why you are in charge.

Captain WORTZEL. That involvement is as a focal point. This committee, the National Operations Security Advisory Committee, has no authority to make a determination. It is simply a forum to ensure that the Government, including Congress, which funds these surveys and the Navy's operating forces, as well as the agencies engaged in the charting are aware of the national security implications of the data.

Mr. STUDDS. Am I going to walk downtown and find the doors to the National Geographic Society locked?

Captain WORTZEL. In no sense.

Mr. STUDDS. On the grounds that their continued publication of those maps threatens the national security?

Captain WORTZEL. In no sense.

Mr. STUDDS. Well——

Mr. WINOKUR. If I may just contribute one comment on that. I think at issue here is the quality and the quantity of the data, so in so sense are charts such as the National Geographic's charts at issue.

Mr. STUDDS. Well, I wouldn't want to be impugning the quality or the quantity of their charts, but certainly, if you are correct in asserting some kind of overriding national-security significance to the kinds of data that have traditionally been wide open to the public and for which this Nation, through the lead of its charting agencies such as NOAA which has acquired, as I understand it, a worldwide reputation for making available to the world fundamental scientific data—I wish I had thought of this one to ask some of the scientists earlier.

To your knowledge, are other nations pondering withholding this kind of data from the world at large?

Captain WORTZEL. Other nations classify their charts.

Mr. STUDDS. They do.

Captain WORTZEL. Yes, they do. The United States does not, and although charts of this type have not been available in the past, we do not contemplate the classification of any chart. Our concerns deal primarily with the digitized data base, the computerized data base, and the production of unclassified charts.

Mr. STUDDS. All right. Obviously, this should be pursued at another time in another forum, but I just can't help thinking what a position the U.S. Navy would be in today if Queen Isabella had told Columbus to shut up about what he found out.

I appreciate your comments. You are an Army captain; is that right?

Captain WORTZEL. Yes, sir, I am.

Mr. STUDDS. OK. Thank you very much.

Let me try one other topic here. Dr. Ross of Woods Hole proposed the creation of an Office of International Marine Science Cooperation to be the focal point for foreign contacts seeking to develop cooperative programs with the U.S. marine scientific community.

Dr. Gross, do you share Dr. Ross' belief that this type of office would be useful in facilitating international cooperation in the area of marine scientific research, and do you believe such an office could accomplish something we are not at present able to accomplish with all of the existing offices and agencies that have some involvement in international research?

Dr. GROSS. Since the Law of the Sea Treaty reached its conclusion, we have followed with great interest the progress of the various research projects which we support to see what problems they have had.

My assessment of our recent experience is that we have had relatively few problems. We have not experienced great difficulties in getting access to other countries' waters.

Perhaps we have not yet had enough experience. So, at this time we are essentially taking a wait-and-see attitude. If, indeed, a problem arises as a significant one, we would feel that such an office might well have a role to play.

We just simply feel that we do not yet have sufficient experience to cast a vote one way or another.

Mr. STUDDS. Mr. Wolff, do you have any comment on Dr. Ross' plan, for example, whether it should be located in NOAA?

Mr. WOLFF. No, sir.

Mr. STUDDS. Mr. Winokur, do you have any comment either on Dr. Ross' proposal or on Dr. Corell's suggestion that we integrate international marine scientific research programs and foreign policy legislation using AID, bilateral agreements, and existing research support programs?

Mr. WINOKUR. The Navy does conduct a number of bilateral programs under the auspices of various exchange agreements with various countries. Within the context of naval operations and Navy research, we have access to a considerable amount of data with our allies.

On the other hand, we are sympathetic with the problem that Dr. Ross has raised. We are currently evaluating the need for such increased activity, other than what we are already doing. We, in fact, have spoken to Dr. Ross and we are currently looking at an initiative ourselves for the future to seek if in someway we can make better use of other foreign data that we are not currently making use of.

With respect to AID and the Department of State, we work with them in those instances that are of common interest, but we normally don't have that much in our research program.

Mr. STUDDS. I am going to ask one last question.

I would like to close by asking each of you if you could identify the one specific thing the Government most ought to be doing to facilitate marine research that we are not doing and are not about to do. I don't care whether it is related to resources, or management concepts, or research priorities, if there were one thing you could change about our present approach to this issue, what would it be?

Mr. WINOKUR. I guess from my perspective, having been the chairman of an interagency study on a unique national asset, that is, the research fleet, one of the issues that confronted us in that study which I would bring to your attention is the lack of a current stated national policy on ocean research. That seemed to be one key issue that was facing us in the context of the study that we were doing, representing the various agencies operating research vessels.

I guess, in that context, I would say a clear statement of what the national policy is in oceanography and ocean research in particular.

Mr. STUDDS. Dr. Davies.

Dr. DAVIES. I would like to return to the issue that we talked about a moment ago and pick up on a comment that Jerry Schubel made which was that we have 1-year appropriations from the Congress. Occasionally, things pop in there, like this estuaries study that was appropriated. Jerry's comment that it would be nice if we had 1 year's planning ahead of time rather than a slug of money with a brick wall at one end where you have no resources to begin with, and a brick wall at the end where the resources dry up. Within that short window of time, you have to gear up to do the work, produce your reports, and you have very little time to get organized and think about it.

It might be a good idea if we had a little more stability in the system. I know that is a difficult thing to ask for, but a little planning money ahead of some of these projects would be an enormous benefit to any research or monitoring or regulatory program.

Mr. STUDDS. Anyone else? This is not compulsory; it is an optional exercise.

Mr. WOLFF. The exciting thing to me about the prospects of finding out more about the oceans is its impact on weather forecasting, since I think that that is where it is most essential and that is where it has the biggest financial impact on human life.

In the possibility of increasing the accuracy of 3- to 6-day forecasts, we need a number of things. The single thing which looks most unattainable to me now is the operational system of ocean satellite observation that is necessary. When the program was transferred from NASA to NOAA, the budget didn't come with it. NASA is now interested in further experimenting with new sensors of limited duration for experiments, where NOAA's problem is that we need operational satellites using existing sensors which have been proven in sufficient number so that we can have the data to make the more accurate weather forecasts.

To me, the budget and the means to put this together is the biggest important problem that I don't see any solution to or any way to get one.

Mr. STUDDS. I would be happy to see more facilities go into your 3- to 6-hour forecasts. [Laughter.]

Very vivid in my mind is standing at midtide one day this summer watching my little sailboat founder and sink in a 50-knot wind and listening to NOAA on the radio simultaneously tell me it was 10 to 15 knots. It is that immediate impact that is of such pressing consequence to some of us.

I understand what you are saying though, and we agree on that, I think.

Do either of the other of you wish to comment?

Dr. WEBSTER. Yes, thank you, Mr. Chairman.

I would like to speak from the point of view of research science. I have watched over 25 years in research institutions a continual erosion of our ability to do research because of an accumulating bureaucratic and micromanagement philosophy. It is primarily happening here in Washington, and the trouble is we all tend to share in it because the motives that have created this seem to have been, each individually, worthwhile. Cumulatively, I think they are causing a burden on our ability to do creative research in this country.

It may not be just confined to oceanography, but if I had my magic wish that you mentioned, I would like to see us go back to a system where we were able to make decisions about funding research to provide more creativity. I think almost everybody in the first panel said something similar when they were talking about block grants and the sociopolitical factors and so forth.

As seen from the oceanographic research laboratories, this has been accumulating and accumulating and accumulating, and it is not making us more creative or productive.

Mr. STUDDS. Dr. Gross.

Dr. GROSS. Mr. Chairman, as my wish, I would focus on manpower. We have had a number of discussions over the years that I have been in the field about the resources and about the facilities. Yet, we seem, I think, we neglect what I believe is the country's most precious resource—our scientific manpower.

My feeling is that we, the Federal Government and the States, are not providing the proper institutional framework to train and to retain the best scientific minds to work on the oceans. Quite frankly, I share some of the concerns that Dr. Webster just articulated.

Ocean science is not a particularly attractive area for a bright person to come into today. I think we are losing through our inability to recruit and to retain the best minds. In summary, I think the primary limiting resource, even more than money, ships, satellites, or anything else, is our ability to retain the best minds to work on the problems and the utilization of our ocean resources.

Mr. STUDDS. Thank you.

I think Mrs. Schneider will agree with me that people who work where we do understand the concept of an area of work where it is hard to attract particularly bright people.

Mrs. SCHNEIDER. I won't take that personally, Mr. Chairman.

Mr. STUDDS. No; it was a generalized conception of the profession.

Mrs. SCHNEIDER. Might I be able to ask Dr. Gross to expand upon how we might cure this dilemma? You surely must have some recommendations. I also serve on the Science and Technology Committee that deals with NSF's budget. We have discussed education extensively and taken action on legislative proposals to increase the number of scientists, engineers, and mathematicians entering the field, but the problem is that we may have these people educated and then there may not be the appealing jobs for them. So, how do we create that employment environment?

Dr. GROSS. I wish I had an answer for you. I ~~can only~~ say, first, that in the Foundation, we too are sharing this concern about the educational side and are, indeed, as you are well aware, attempting to increase and improve our support at that level.

I am concerned, at the institutional level, once they enter the institutions, I think with the demise of ONR's institutional support role in the 1960's that no other agency and no State has been able to step in and fill that gap. I think that the field as a whole has been remarkably successful in taking very meager resources, often with uncomfortable constraints. I think some of the frustration that you heard from the first panel is that they have been literally scrounging to stay alive.

I don't see too much relief. I think more research money would be of some help. As you probably know, within the Foundation, we have a small experimental program to stimulate competitive research [Epscor] in which we attempt to work with States which are less successful in attracting Federal funding to help them to improve the competitiveness of their university-based scientific manpower. In ocean science, it has been a real success in Maine.

I don't think we know, really, how to achieve our desired results. Rather than have a large program, I believe it would be better to try a few small ones and see if we can devise better institutional support mechanisms.

Mrs. SCHNEIDER. Thank you

Thank you, Mr. Chairman.

Mr. STUDDS. Thank you.

At this point in in the record, without objection, the statement of Congressman Pritchard will appear.

[Statement of Mr. Pritchard follows:]

STATEMENT OF HON. JOEL PRITCHARD, A U.S. REPRESENTATIVE FROM THE STATE OF WASHINGTON

Mr. Chairman, I am most pleased with the scheduling of this afternoon's hearing on the status of marine research in the U.S. and would like to commend you and the Subcommittee Chairman, Mr. D'Amours, for ensuring the time to examine this important subject. Marine scientific research within this country is an area well worthy of this Subcommittee's scrutiny, and I am looking forward to hearing from the panel members who are here today to discuss our current capability and where we go from here.

Today's hearing will focus on the capacity within the U.S. to conduct marine scientific research—both within the Federal Government and the academic community. The time is ripe to start building an oversight record on that capacity for several reasons. Major innovations in technology are making it possible to greatly improve our understanding of the oceans. For example, the use of satellite remote sensing allows us to study ocean-wide processes synoptically, and in real time, which is invaluable in the development of environmental prediction models. Also, very sophisticated microprocessors have been developed which can be used to manage vast amounts of data. And in these times of fiscal austerity, it is crucial that our research dollars are spent in the most cost-effective manner possible, without duplication of effort.

For this to occur, we must understand that oceanographic research should be a cooperative venture in this country. As Ranking Member of the Subcommittee on Oceanography for almost eight years, I am not terribly encouraged by the way priorities in this area are established and followed through on by the Federal agencies responsible for funding our marine research infrastructure in this country. As part of this process, we need better identification of research needs, and coordination between the scientific community and Federal agencies in developing priorities. I question whether the necessary mechanism for this coordination exists. If it does, has it been effective? How can it be improved? And if an effective forum for coordination does not exist, how should one be developed?

I would like to again thank the Subcommittee Chairman and the Acting Chairman for their interest in this matter. I am glad for the opportunity to get these issues out on the table and look forward to receiving the testimony today. Thank you.

Mr. STUDDS. Gentlemen, we thank you for your patience and your contributions. I found this most informative, and I think that the hearings, when printed, will be a source for a good many people to reflect on, hopefully constructively, for some time to come.

Thank you very much, indeed.

The subcommittee is adjourned.

[Whereupon, at 4:27 p.m., the subcommittee recessed, to reconvene, subject to the call of the Chair.]

[The following was submitted for the record:]

QUESTIONS FOR RECORD FROM REPRESENTATIVE CLAUDINE SCHNEIDER AND REPLIES FROM THE NAVY DEPARTMENT

Question 1. What is startling about the NOAA data?

Response. The NOAA data are of unprecedented accuracy and completeness. Moreover, because the results of the NOAA surveys are digitized, they are readily transferable, and, therefore, require controls on their release. The current plan to insert the data into a bank which is automatically provided to the USSR would provide them with a bonanza of militarily important information, without the huge expense involved in collection, without the political uproar that would occur should they undertake such a survey in our EEZ and without having to subject their EEZ to a corresponding survey by the US (an act they would strongly oppose).

Question 2. Isn't there a conflict when Navy classifies data which NOAA collects as unclassified?

Response. Yes, there is a conflict. The data NOAA collects requires the protection classification affords. Under the terms of Executive Order 12356, 2 April 1982, subject: "National Security Information," Section 1.1(a)(2), the unauthorized disclosure of information which reasonably could be expected to cause serious damage to the national security should have "SECRET" applied to the information. Section 1.3(a)(6) states, "Information shall be considered for classification if it concerns . . . scientific, technological, or economic matters relating to the national security." On the other hand, Section 1.6(b) states, "Basic scientific research information not clearly related to the national security may not be classified." The NOAA bathymetric surveys are being conducted in an established technical mode, using technology which is about 10 years old, the results of which are directly related to the national security. The survey program which is aimed at aiding commercial enterprises to locate and exploit EEZ resources, is also highly useful to adversaries of the United States including terrorists (e.g., mine operations). This conflict is currently being discussed in an interagency forum under the aegis of the National Operations Security Advisory Committee, a committee chartered by the Interagency Group/Countermeasures of the Senior Interagency Group-Intelligence. The National Operations Security Advisory Committee (NOAC) serves to provide an interagency forum within the executive branch for discussion, consultation, and coordination of Operations Security issues. Its purpose is to resolve interagency problems, and, although it has no authority, it provides recommendations for the resolution of such problems to the Interagency Group/Countermeasures. The NOAC Chairman would be happy to provide a classified briefing for the committee which outlines the many national security issues which include several areas of concern.

Question 3. Why is the Navy's data on the contour on the ocean bottom classified?

Response. Detailed and highly accurate bottom contour data are collected and used extensively to support strategic and tactical naval operations. Accurate environmental data are essential to military operations and well worth the expense involved in producing it. Such data are equally valuable to an adversary and therefore must be kept from him to the maximum extent possible.

Question 4. Are Navy and NOAA (National Oceanic and Atmospheric Administration) unnecessarily duplicating efforts in charting the EEZ?

Response. Some of the area scheduled in the EEZ survey program is currently covered by US Navy data. Classified Navy bathymetric data can be made available, on a case-by-case basis, to appropriately cleared non-DoD users to avoid unnecessary expenditure of tax dollars. However, Navy data differ from NOAA data in scale, unit of measurement, and control.

EDITOR'S NOTE.—The following letter was sent to each of the witnesses. In addition, specific questions were also sent. Responses were received from NSF, NOAA, ONR, EPA, UNOLS, Dr. Baker, Dr. Ross, Dr. Heath and Dr. Boesch.

HOUSE OF REPRESENTATIVES,
COMMITTEE ON MERCHANT MARINE AND FISHERIES,
Washington, DC, October 12, 1984.

Dr. GRANT GROSS,
National Science Foundation,
Washington, DC.

DEAR DR. GROSS: First, I would like to thank you for your participation in the recent Oceanography Subcommittee hearing on marine research. I believe that this hearing provided an important beginning in the development of an oversight record on the status of marine research in the U.S., both within the Federal Government and the academic community. I also believe that your direct involvement in the hearing assisted the Subcommittee in making significant progress toward a better understanding of some of the issues which need to be addressed.

Second, I would like to make the observation that as a result of recent technical advances and increased capabilities in such areas as satellite remote sensing, sophisticated microprocessors, and other instrumentation, there is the potential for significant new initiatives in both basic and applied marine research which could lead to substantial benefits to our nation and the world. As the Ranking Minority Member of the Subcommittee on Oceanography for almost eight years now, I would also like to point out that I have not always been terribly encouraged by the rather ad-hoc process by which priorities are established, coordinated, and followed through by the Federal agencies responsible for funding marine research and the necessary infrastructure to carry it out. In order for the U.S. to continue to play a leadership role in Oceanography and in order to conduct the type of "big science" projects which will be required, we need a clearer identification of research needs and initiatives, and improved coordination between the scientific community and the Federal agencies involved in the development of marine research priorities and budgets. In this vein, I would appreciate any further comments or suggestions you might have for improving the process by which we establish priorities and initiatives for the enhancement of our overall marine research capability.

Finally, I am attaching a list of specific questions which we did not get an opportunity to discuss during the hearing. I would greatly appreciate your answers to these questions, as well as any additional comments you wish to submit in order to provide as complete a record as possible. In order to complete our record on this subject as soon as possible, I would appreciate receiving your response no later than October 31, 1984.

Once again, I would like to thank you for your contribution to our oversight hearing and your continuing contribution to marine research generally.

Sincerely,

JOEL PRITCHARD,
Ranking Minority Member, Committee on Merchant Marine and Fisheries.

Attachment.

QUESTIONS FOR NSF

1. Through the Board on Ocean Science Policy of the National Academy of Sciences, it is our understanding that the Advisory Committee for Ocean Sciences of NSF has undertaken a study on trends in ocean science and the role of NSF during the next decade. Please describe how these new initiatives are to be implemented, i.e., funding mechanisms, research prioritization, and instrumentation support. What are the budgetary implications for the other ocean research funding agencies, specifically NOAA, ONR and EPA?

2. As technology drives oceanographic reearch into a new era of data collection, the ensuing problems for data management are enormous. Not only are new kinds of data being generated, both nationally and internationally, but it is being produced in vast quantities. What is NSF doing to ensure data quality and format standardization? Will it be adequate in the future?

3. You stated in your testimony that the function of ships is changing in a fundamental way. Please explain. Is our present planning effort adequate to incorporate these changes? How much is NSF planning to commit for this new fleet?

4. You stated in your testimony that NSF and NASA plan to ensure that U.S. academic oceanographers are able to use the data stream from satellites in their research projects. Please tell us exactly what is being done.

NATIONAL SCIENCE FOUNDATION,
DIVISION OF OCEAN SCIENCES,
Washington, DC. November 15, 1984.

Hon. JOEL PRITCHARD,
Committee on Merchant Marine and Fisheries,
House of Representatives,
Washington, DC.

DEAR MR. PRITCHARD: Thank you for your letter of 12 October commenting on the recent Oceanography Subcommittee hearings on marine research and on the process through which priorities are established and initiatives proposed for oceanographic research in the United States. You suggest in your letter that "clearer identification" may be needed "of research needs and initiatives, and improved coordination between the scientific community and the Federal agencies involved in the development of marine research priorities and budgets." I would like to comment on these issues, addressing first the issue of most importance to us—coordination between the scientific community and the National Science Foundation.

We are very proud of what we consider to be an excellent record of close and effective communication, cooperation and coordination with the academic basic oceanographic research community. This interaction is a keystone of our ocean sciences program and we intend to continue to look to this community to provide us with more new and exciting scientific ideas and challenges.

The primary inputs we rely on in our establishment of priorities and adoption of new initiatives come from scientists in the community. These scientists are consistently encouraged to submit new ideas to use through research proposals and through other informal and formal channels such as scientific workshops and symposia, the National Academy of Sciences' Board of Ocean Science and Policy (NAS/BOSP), and the NSF Ocean Sciences Advisory Committee. Most recently the Advisory Committee completed a long-range plan for the NSF ocean sciences program which was then endorsed by the NAS/BOSP.

New ideas submitted to us in research proposals are carefully and thoughtfully reviewed before we make final decisions as to the priority and financial support merited. A major factor in this review is the advice we receive through peer evaluation of the proposed research. These proposals are mail-reviewed by individual scientists knowlegeable in the proposed area(s) of research and many proposals are also then reviewed by panels of experts. Final recommendations on these proposals are made by the program manager(s) in the appropriate area(s) and then approved by a section head and the division director. A description and analysis of this review process prepared is attached for your information.

We involve the scientific community directly in acquisition, scheduling and schedule coordination of academic research vessels through the University National Oceanographic Laboratory System (UNOLS). Representatives of ship operating and ship-using institutions meet under UNOLS to assess and advise on a broad range of issues related to needs and operations of the U.S. academic research fleet and other facilities. NSF and other concerned Federal Agencies provide financial support for UNOLS and participate in UNOLS meetings, interacting regularly with the various UNOLS committees, officials and staff.

As I reported in my testimony to the Oceanography Subcommittee, NSF is working closely with scientists in the academic research community with respect to evaluation and planning of a number of future major ocean science projects which intend to make substantial use of recent technological advances, primarily with respect to satellites, supercomputers and marine seismic systems. These projects include the Study of the Tropical Ocean and Global Atmosphere (TOGA); the World Ocean Circulation Experiment (WOCE); and Ocean Flux Experiment; and a study of the Oceanic Lithosphere.

The NSF ocean sciences program is centered in our Division of Ocean Sciences. Our Divisions of Atmospheric Sciences, Polar Programs, and Earth Sciences also sponsor some ocean science research and related research. All of these Divisions interact continually regarding programs of mutual interest.

Your letter suggests that you are also concerned with the manner in which the Federal Agencies jointly address issues related to oceanographic research. The National Science Foundation works closely with other individual Federal Agencies, especially the Office of Naval Research (ONR) and NASA, in areas of mutual interest.

NSF and ONR co-sponsor programs in all subdisciplines of oceanographic research. We are now working very closely with NASA with respect to development of new remote sensing programs related to ocean sciences. The latter efforts are discussed in more detail in our answers to the questions presented to us in the attachment to your letter.

With respect to multi-agency coordination, the recent record is not as good as we would like but is now improving. Over the past twenty-five years there has been a series of Federal interagency coordinating mechanisms for ocean sciences. The Interagency Committee on Oceanography (ICO) was the first of these during the early 1960's. It was very effective, but, of course, the individual Agency programs were much smaller and much more sharply focused then. The ICO was succeeded by the National Council on Marine Resources and Engineering Development—the so-called Marine Sciences Council—which was successful at focusing attention on newly-growing concerns of marine resource exploitation and wider use of our coastal areas. Then the Interagency Committee on Marine Sciences and Engineering (ICMSE) and the Committee on Atmosphere and Oceans (CAO) followed. The latter two Committees have not been very effective.

In 1982 the Administrator of NOAA, with encouragement from the National Science Foundation and the Department of the Navy, reactivated the then-dormant CAO in order to improve interagency coordination in ocean sciences. As a result, the CAO and its subcommittees on atmospheric and marine research have become increasingly active. It is too early to tell whether this mechanism will fully meet needs for multi-agency coordination in ocean sciences, but the National Science Foundation is actively pursuing this objective.

I have also prepared for your use comments with respect to the specific questions you addressed to me in your letter. These are provided in the attachment to this letter. Please do not hesitate to call on us if we can be of further assistance.

Sincerely,

M. GRANT GROSS, *Director*.

Attachments.

RESPONSE TO QUESTIONS OF MR. PRITCHARD BY NSF

1. Significant new ocean science initiatives will require additional funds. To the extent possible, needs will be met by continuing redirection of related activities in our core program. The latter, however, will be both limited and difficult because of our broad responsibilities, diversity in the field, the soft-money dependency of the community, and the lack of major real growth in Federal support for basic oceanographic research since the early 1970's.

Actual projects will be selected and funded by the traditional peer review process. Some planning and operational activities needed to support planned projects (e.g., hydrographic and geochemical observations, deployment of current meter moorings and floats, and development of improved seismic capabilities and biological instrumentation) may be funded through cooperative agreements with consortia or individual oceanographic institutions.

At present the major budgetary implications for other Agencies in moving ahead with these scientific initiatives are for the satellite programs sponsored by NASA and by operational units of the Navy (not ONR). These programs will cost NASA roughly $750,000,000 over the period 1985–1995.[1] Interagency (and international) coordinating committees have been established for some research programs for which planning is already underway, e.g., the World Ocean Circulation Experiment (WOCE) and the Study of Interannual Variability of the Tropical Ocean and the Global Atmosphere (TOGA). NOAA has budgeted roughly $7,000,000 per year for long-term observational programs related to TOGA. NOAA activities associated with WOCE may include sea-level, ship-of-opportunity, and similar observational programs. Such programs could require augmentation of the NOAA budget at approximately $5,000,000 per year. ONR and EPA are not likely to be impacted significantly by these new programs, although they may derive some benefits from the results of these programs.

2. Computing capabilities to date have kept up with data acquisition capabilities in ocean sciences. The National Center for Atmospheric Research (NCAR) plans to acquire an advanced vector computer. If 20% of this computer's capability is dedicated to ocean sciences, if marine geological and geophysical computing needs are met elsewhere, and if academic oceanographers obtain the manpower and communi-

[1] "Oceanography from Space: A Research Strategy for the Decade 1985–1995." Joint Oceanographic Institutions, Inc., 2100 Pennsylvania Ave., NW., Washington, DC 20037

cations capabilities necessary to use supercomputer systems effectively, oceanographers will be able to meet future needs.

The kinds of future research programs that I described in my testimony to the Subcommittee will generate substantial new data sets and the data will be in new formats as well. However, development of such new formats is not a problem. NASA is presently supporting a pilot project for handling ocean-related satellite data.

Managing these new data sets and assuring data quality are likely to pose significant challenges. Our experience indicates that it is best to deal with these problems by assuring that they are addressed within the scientific plan that will be developed for each funded research program. Again as an example, Professor Ferris Webster of the University of Delaware has studied data management problems associated with ocean-related satellite data and has presented to Federal Agencies a series of recommendations which we will be addressing over the next several years.[2]

3. Changing research requirements are increasing demand for research vessels with specialized capabilities. For example, modern geophysical seismic reflection studies require new and more powerful compressors and associated equipment which may occupy more space on a new research vessel than engines. New submersible tenders, seafloor mapping vessels and acoustically quiet ships are also required to meet specific present needs.

Vessels must be carefully scheduled in order to assure that specific capabilities are available for research projects in different regions at particular times. Such scheduling has become increasingly complex, demanding longer lead times and close and continual cooperation among all concerned research institutions.

At the same time, global and interdisciplinary field studies coupled to remotely-sensed data will required increased use of well-equipped general-purpose ships, not only to provide so-called "ground truth" but also (and more importantly) to extend these observations down through the water column and to study important problems identified in real time by satellites. These new general-purpose vessels will need to carry large scientific parties, have storage and handling capabilities for extensive sampling systems, and be equipped with state-of-the-art instrumentation, communications links to high-speed computers, and sophisticated navigation systems.

Overall, ships must continue to fulfill an essential and continually evolving role in oceanographic research. Our present long-range plan identifies a need for three new ships. They include: a ship with a state-of-the-art multi-channel seismic reflection capability (estimated to require a Federal contribution of $15,000,000 in fiscal year 1987) and two large general-purpose ships (estimated to cost $50,000,000 for construction and outfitting over the three-year period fiscal years 1988–90). With these resources, we should be able to meet the needs of our initiatives and maintain an adequate research fleet to support our high-quality core research program. Further examination of alternatives and consideration of priorities will, of course, precede any formal budget request.

4. An extensive communications network will link NASA data centers with academic supercomputer centers. Smaller distributed computing networks will link oceanographic laboratories with regional and national supercomputing centers. In this way satellite data sets can be assimilated with in-situ field observations and sophisticated ocean models and results can be analyzed locally. Such networking is being planned and tested by NASA through its pilot ocean data study referenced earlier.

Response to Questions of Mr. Pritchard by NOAA

Question 1. A recent report by the Joint Oceanographic Institutions, Incorporated, details a ten-year research program using oceanographic satellites and related measurements. How does NOAA plan to incorporate any of this program into their future planning in the air/sea, and what similar research and operational programs in oceanography does NOAA plan?

Answer. NOAA plans a number of programs that will take advantage of major investments in oceanographic satellites by other agencies, and other countries. Many of the data sets that will be available from the ocean satellites planned for the 1985–1995 time period will be incorporated into NOAA's marine operational and research programs. For example, NOAA will use scatterometer wind, sea surface temperature, and altimeter data from the NROSS mission, and altimeter data from

[2] "An Ocean Climate Research Strategy," Ferris Webster, National Academy Press, Washington, DC 1984

the TOPEX mission, in the following programs: TOGA (Tropical Ocean & Global Atmosphere), EPOCS (Equatorial Pacific Ocean Climate Studies), STACS (Sub-Tropical Atlantic Climate Studies), modeling at the Geophysical Fluid Dynamics Laboratory, forecasts at the Ocean Products and National Meteorological Centers, and the geodesy programs of the National Ocean Service. NOAA examines uses of the data from the Ocean Color Imager and Geopotential Research Missions (GRM) for ongoing programs.

The instrumentation aboard these satellites will help provide observations from ocean areas which now have little data. These satellite sensors will provide wind, wave, and ice information to help preparation of timely weather and oceanographic warnings and forecasts. These types of ocean satellite measurements also will be of significant importance to NOAA for better understanding of ocean circulation needed for understanding the ocean's role in climate.

A combination of satellite and sea-based measurements over time helps to monitor the ocean, predict weather and climate, and participate in international studies to understand the global environment.

Question 2. Charges have been leveled against the National Oceanographic Data Center that it is inefficient, ineffective and outdated. What steps is NOAA taking to update this facility, to standardize the formatting of incoming information, to provide quality control to guarantee accurate information is included, and how does NOAA plan to handle the exponential growth of data gathered by satellites and other sources in the next few years?

Answer. The National Oceanographic Data Center is efficient, effective, and up-to-date. NOAA has taken steps to update this facility; to standardize the formatting of incoming information, and to guarantee accurate information is included in its data files. NOAA plans for handling the exponential growth of data gathered by satellites and from other sources in the next few years are part of our current National Environmental Satellite, Data and Information Service (NESDIS) Long-Range Plan.

The National Oceanographic Data Center (NODC), like other technical organizations, has had to change and evolve in order to keep pace with accelerating advances in science and technology. In the past three years NODC operations and procedures have been greatly improved and updated by strong, effective management actions. These actions have resulted in both organizational and technical improvements in effectiveness and efficiency.

ORGANIZATIONAL IMPROVEMENTS

In 1981 the Director of NOAA's Environmental Data and Information Service completed an NODC Program Evaluation.

Implementing the recommendations from its program evaluation, NODC reorganized in March 1982. The new NODC organizational structure: (1) established clearer lines of management responsibility, (2) facilitated adoption of improved data base management methods and techniques, and (3) corrected specific areas of weakness identified by the program evaluation team. The NODC reorganization:

Consolidated ADP operations within a single organizational component (ADP Support Division).

Established the Office of System Planning and Integration as the single focus for NODC systems planning and development.

Delegated responsibility for the physical security and maintenance of the NODC data files to the Chief of the Inventory and Archives Branch with the title and authority of Data Base Administrator.

Created the position of Data Administrator on the staff of the NODC Director with principal responsibility for the quality and scientific integrity of the NODC data files.

NODC developed a manual of Standard Operating Procedures which improved its day-to-day operations.

NODC participates in developing products for NOAA Regional Ocean Service Centers in Seattle and Anchorage. A NESDIS/NODC Liaison Officer is the principal NESDIS representative at each of these sites. To provide users with easier access to its data, NODC is exploring the development of regional subsets of its data inventories and data fields to support the areas of responsibility of the ocean service centers.

TECHNICAL IMPROVEMENTS

In November 1982 NODC conducted an Internal Program Review to develop and implement an action plan for technical improvements.

In consonance with NESDIS long-range plans, NODC has upgraded its computer facilities. In late 1981 the archive data files of NODC and the other NESDIS data centers were consolidated on a single computer that is the central node of a NESDIS computer and telecommunications network called the Data Archive Management and User Services (DAMUS) system. In mid-1984 the DAMUS central computer was upgraded (to a Sperry 1100/62) to provide greater data storage capacity and faster response time. A mass storage device that decreases costly magnetic tape mounts will be a future part of this system. In December 1984 NODC will replace its in-house minicomputer with a much more powerful machine (DEC VAX 11/750). A new software system consolidating improved data entry and quality control procedures will be operational on this machine in July 1985.

NODC continues improving data acquistion, data processing, and data quality control.

In 1983, at NODC request, the National Science Foundation sent a statement to all their grantees requesting timely submission to NODC of appropriate data from their projects.

In both 1983 and 1984, NODC set new all-time high data processing records. From FY 1983 to FY 1984 oceanographic station data processing increased 26 percent (from 36,073 to 45,642 stations); bathythermograph data processing increased 88 percent (from 73,822 to 128,587 observations).

To meet the projected influx of ocean temperature profile data from new climate-related studies such as the Tropical Ocean-Global Atmosphere (TOGA) Experiment, NODC is replacing outdated equipment currently used to digitize expendable bathythermograph (XBT) data. A new microprocessor-based system is being procured in cooperation with the NOAA National Marine Fisheries Service and the U.S. Navy Fleet Numerical Oceanography Center so data can be freely exchanged in a compatible format among these organizations.

Two quality control workshops—one for physical data (March 14, 1984), and one for chemical/biological data (April 30, 1984)—helped in the design of NODC's new data entry and quality control system. The workshops were coordinated by the NODC Data Base Administrator and attended by selected NODC personnel and invited outside experts. The new system will incorporate enhanced versions of NODC's environmental quality control (water mass) models that have been a primary QC tool for many years.

From its experience as data manager for both deep ocean research projects and coastal environmental studies, NODC has developed standard data formats and codes. For example, NODC has developed ancillary code files to support processing of chemistry and biology data. The chemistry codes (adapted from the registry numbers of the Chemical Abstracts Service) include the pollutants designated by the Environmental Protection Agency for priority study. The NODC Taxonomic Code facilitates automated storaged and retrieval of biological data. The fourth edition of the code (containing 46,000 entries, nearly twice as many as the third edition) became available in October 1984. Both the chemistry and taxonomic codes and NODC formats have been widely adopted by research in other Federal agencies, universities, and private research institutions. Region 10 of the Environmental Protection Agency recently adopted NODC data formats for storage and dissemination of marine data resulting from activities of Section 301(h) of the Clean Water Act. Over the past two years NODC has also developed software to convert submitted data to standard NODC formats. This makes available data that could not previously be integrated into the archive data files.

NODC's new Visiting Scientist Program will improve NODC's technical capabilities through increased contact with the oceanographic research community. By means of this program funds will be provided to support scientists interested in conducting research that will support NODC's mission. The primary criterion for selection of winning proposals under this program will be clear demonstration of tangible benefits to NODC from the project results.

NODC is preparing to meet future responsibility, especially those resulting from the growth of data from satellities and other remote sensing platforms.

NESDIS has developed a long-range plan for the integration and use of satellite data. This plan involves all of the NESDIS data centers so that there will be a systematic approach to acquiring, processing, storing, and disseminating original data and derived values. The NODC will participate in this activity by storing and distributing oceanographic data values and products. NESDIS will establish Working Groups to explore appropriate ways to improve and increase the integration and use of satellite data in Centers. The Working Group for Satellite Data and Oceanography will have representatives from NODC, the National Climatic Data Center's Satellite Data Services Division, and the Office of Satellite Research and Applications, Oceanic Sciences Branch.

NODC is also preparing for the future by integrating the NODC/NESDIS plans for remotely sensed data with national plans being developed for an ocean-related climate study that is expected to dominate ocean data collection efforts during the next decade—the Tropical Ocean—Global Atmosphere (TOGA) Experiment. NODC representative are currently members of data management planning groups for this project and the NODC Northeast Liaison Officer has been designated as the Data Manager for one component of TOGA.

Question 3. What is NOAA's current role and what future role is planned for the Committee on Atmosphere and Oceans (CAO) and the Subcommittee on Marine Research?

Answer. The Administrator of NOAA has traditionally been appointed Chairman of the Committee on Atmosphere and Oceans (CAO) by the Chairman of the parent organization, the Federal Coordinating Council for Science, Engineering, and Technology. The Office of the NOAA Administrator provides executive secretariat support for the CAO. The Department of Commerce (including NOAA) is represented separately on CAO by the Deputy Administrator of NOAA. Through the chairmanship and participation as an active Committee member agency, NOAA is a very important contributor to the work of the Committee on Atmosphere and Oceans.

The CAO itself serves as a "broad of directors" for various subcommittees which perform many of the actual coordinating responsibilities of CAO. One major element, the Subcommittee on Marine Research (SMR), has become a forum for senior agency managers to consider Federal marine science topics of common interest. Activities of the SMR have included analysis of trends in the total Federal marine science budget, a review of the satellite oceanography program of NASA, and an evaluation of the implications of U.S. withdrawal from UNESCO for marine science. During FY 1985, SMR plans to examine such topics as increased use of aircraft remote sensing for coastal studies, oceanographic data management (particularly the implications of oceanographic satellite observations), the deterioration of the facilities' "infrastructure" for marine science, and trends in manpower availability for marine science and technology applications.

Question 4. Would you please submit for the record a copy of the MOU between NOAA and USGS and NOAA and EPA, as well as a brief description of agreements that now exist or that you are presently working towards with the NSF and the U.S. Navy?

Answer. NOAA has a number of MOUs with the U.S. Geological Survey. Given the context of the Subcommittee's September 26, 1984, hearing, and NOAA's testimony, we have assumed the MOUs of interest are the overall agreement for cooperation between the agencies and the recent one for a cooperative bathymetric surveying program of the U.S. Exclusive Economic Zone. Copies are attached for the record. Similarily, NOAA has several MOUs with the Environmental Protection Agency (EPA). A copy is attached of the overall umbrella agreement establishing the basic policy of cooperation and the relative roles of the two agencies, which became effective October 29, 1984.

NOAA has four agreements with the National Science Foundation (NSF): (1) for shared funding of research grants to universities for global atmospheric research; (2) with the U.S. Geological Survey as a third party, for earthquake research; (3) to facilitate transfer of NOAA funds for use of University-National Oceanographic Laboratory System (UNOLS) vessels; and (4) for shared funding of the submersible ALVIN.

NOAA and the U.S. Navy have several hundred agreements. They range from letters of understanding dealing with operational details, some in the form of specific work tasks or exchanges, to MOUs covering major data exchange and cooperative oceanographic research efforts. In order to consolidate these agreements, a broad agreement is being drafted under which these and other individual activities can be carried out in a more simplified manner.

Question 5. You state in your testimony that the NOAA fleet will not need replacement until the year 2000, yet the 1983 report of the Federal Oceanography Fleet Coordination Council, which functions with a representative from NOAA, recommended that a coordinated vessel replacement plan be initiated by NOAA in 1984. Will you please explain the change in direction for NOAA's fleet and the reason for the change?

Answer. The ships in the NOAA fleet have been maintained in excellent condition due to the management procedures of the NOS and the NOAA Corps. Funds have been provided by Congress for routine maintenance and for mid-life rehabilitation in U.S. shipyards. The basic hull and machinery in these vessels will operate through the year 2000 if these conditions are maintained.

The scientific equipment for observation, data collection, and data processing is relatively obsolete. A program has been initiated in FY 1984 to replace these systems.

No proven new design for research and survey ships is currently available which would be economically justified for NOAA requirements. NOS will continue to monitor developments in this field.

The requirements for the NOAA fleet are continually changing. Currently we see the need for large ship time, multi-beam survey capability, and an upgrade of computers and positioning and observing equipment. Alternatively, demand for smaller ships is leveling off and single bean hydrographic survey needs are declining, except in Alaska.

Memorandum of Understanding Between the Environmental Protection Agency and the National Oceanic and Atmospheric Administration

I. Purpose

It is in the national interest that related program responsibilities of the National Ocean and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA) be closely coordinated, mutually supportive, and clearly understood by both agencies. Accordingly, there is hereby established a EPA/NOAA Interagency Committee for Program Coordination to coordinate program responsibilities for mutual benefit and support, facilitate information exchange and resolve conflicts between the agencies.

It is also agreed that the agencies may develop additional agency agreements to guide activities of individual work groups created by the agencies. Such groups may be for any appropriate purpose, but would be subject to all laws and regulations binding the respective agencies.

These activities respond to the mutual interest of NOAA and the EPA in encouraging responsive and efficient management of the Nation's resources in a manner which would have environmentally sound consequences for the oceans and atmosphere.

II. Provisions

The functions of the Interagency Committee for Program Coordination shall include but not be limited to:

Identifying specific issues and program areas to be coordinated or addressed by both agencies, through work groups or some other mechanism.

Arranging for transfer of technology data, information, and research findings of mutual interest between the agencies.

Arranging to cooperate, support and where appropriate, integrate programs of mutual responsibilities and interest. Such cooperation shall be encouraged at both the National and Regional level.

Exchanging appropriate budgeting and program planning information.

The Committee shall be jointly chaired by the Deputy Administrators of NOAA and EPA. There will be no more than 6 members from each agency, to be determined by the respective chairpersons and consisting of officials representing affected program areas.

The Committee will meet at least twice a year, with additional meetings as mutually agreed upon. All current coordination activities will continue under the review of the Committee. All future coordinating mechanisms will be developed with the full knowledge of the Committee. Issues upon which there is no consensus will be referred to the Administrators of EPA and NOAA.

The Committee will identify action items and schedules. The Committee may create work groups to address and coordinate specific issues and program areas. Support for the Committee and coordination of the activities of the work groups shall be provided by the Director of the Office of Federal Activities (EPA) and the Director of the Office of Policy and Planning (NOAA).

III. Authorities

The Environmental Protection Agency has statutory authority to regulate the pollution of the nation's air, water, solid waste, pesticides, noise and radiation. This includes setting and enforcing environmental standards; conducting research on the causes, effects, and control of environmental problems; and assisting State and local cooperators.

The National Oceanic and Atmospheric Administration has statutory authority to observe, report the state of the atmosphere, rivers, and oceans, and prepare and issue warnings and forecasts of atmospheric, flood and ocean conditions to ensure the protection of life and property and to further governmental and commercial activities; to operate environmental satellites and archives for the United States; to manage and promote marine and anadromous fish and other living resources; to manage, with the states, the coastal zone; to provide research in support of all these activities; and to provide research and services to users and managers of the oceans, atmosphere and coastal zone.

Areas of mutual authority include but are not limited to: Pollution Monitoring; Ocean Waste Disposal; Marine Research and Monitoring; Atmospheric Research and Monitoring; Estuarine Research; Coastal Resources and Wetlands; and Environmental Data.

Nothing in this agreement alters the statutory authorities of the Environmental Protection Agency or the National Oceanic and Atmospheric Administration. This agreement is intended to facilitate those statutory requirements through cooperative efforts such as consultation on policy matters and mutual research and technical assistance promoting oceanic and atmospheric quality.

IV. DURATION OF THE AGREEMENT

This agreement becomes effective on the date of signature by both parties and continues for 5 years or until modified by mutual consent or terminated by either party.

RESPONSE TO QUESTIONS OF MR. PRITCHARD BY OFFICE OF NAVAL RESEARCH

Question 1. The Joint Oceanographic Institutions, Inc., has just completed a study of the oceans from satellites during the coming decade. Which other Federal agencies have been involved in the planning of the Navy Remote Ocean Sensing System (N-ROSS) mission, and to what extent? How about when the satellite is operational? Will the data be available to the academic community?

Answer. The N-ROSS concept, including sensors to be carried and the concept of operations, was developed by Navy; however, the Navy views N-ROSS to be of importance to both the operational Navy and the research community. N-ROSS is a collaborative program that was designed to make maximum use of existing hardware and ground support systems. N-ROSS is scheduled for launch in June 1989. N-ROSS will provide a source of integrated data vital to prediction of oceanic conditions for ASW operations, placement of forces and employment of advanced weapons systems. N-ROSS will measure surface winds with a scatterometer (NSCAT); sea surface temperature with a microwave radiometer; ocean waves, eddies and fronts with an altimeter; and atmospheric water vapor, precipitable water and soil moisture with a microwave imager (SSMI).

From the beginning it was Navy's plan to use the launch, command and control facilities of the Defense Meteorological Satellite System. Thus, Air Force will manage that aspect of the project. Approximately one year after Navy first proposed N-ROSS, NASA offered to provide the scatterometer sensor for sea surface winds for N-ROSS, contingent upon Navy allowing NASA to upgrade the scatterometer to gain better wind direction. NASA will provide the scatterometer. At approximately the same time of the NASA offer, NOAA offered to provide the NOAA-D spacebus and $20 million for sensor integration; however, in December 1983, OMB ordered NOAA not to provide NOAA-D or the $20 million. As it stands today, because of congressional action the N-ROSS project may still receive NOAA-D (the availability cannot be determined before December 1984), but the $20 million will not be provided.

Although the satellite is designed to improve operational forecasts of oceanographic and atmospheric conditions for Navy purposes, the data will be available to the civilian oceanographic community, which should lead to further advances in satellite oceanography. When N-ROSS is operational, the data will be transmitted from the spacecraft through the Defense Meteorological Satellite system encrypted data relay system to Fleet Numerical Oceanography Center (FNOC) when the data will be processed. At that point the processed data will be made available to NOAA for further distribution to other federal agencies, private industry and academia. The scatterometer raw data will be processed at FNOC along with the other sensor data—but the raw data from this sensor will also be simultaneously transmitted to

NASA/JPL Pasadena for research use by the NASA/JPL scatterometer science team.

Question 2. How is the increasing U.S. remote sensing capability being factored into the overall U.S. oceanographic research effort? What are the implications on the composition, distribution and management of research platforms?

Answer. Recent progress in physical oceanography has provided new insights which suggest that an ocean predictive capability may be achievable for synoptic scale events occurring over days to weeks and for spatial scales from 10 to 200 kilometers. Advances in observational capability and planned remote sensing satellite systems, such as the Navy's GEOSAT and N-ROSS satellites, coupled with increased modeling sophistication and computational power combine to suggest that the time is ripe to improve our understanding of global and mesoscale circulation and to develop a predictive capability. Central to future advances in this area is the availability of the Navy satellites and planned NASA satellites, such as TOPEX.

In recognition of the fact that we have for the first time the necessary components to address synoptic scale oceanographic problems, the Navy has approved a major five year program in real-time synoptic ocean prediction which takes advantage of planned advances in remote sensing capability. In addition, NSF, in their long range planning, has also proposed a global circulation program which combines satellite-derived information with shipborne field efforts to provide requisite ground truth and input data. The availability of the remotely sensed data is vital to these efforts and future advances in circulation and ocean modeling.

At the present time, advances in remote sensing will probably serve to increase the requirements for ship time in support of the above mentioned programs. A critical component of planned future Navy and NSF studies in ocean circulation is the conduct of at-sea measurement programs to provide ground truth and data required to develop and evaluate prediction models, and to understand fully the properties and dynamics of the water column. Therefore, the advent of oceanographic satellites will not diminish the need for oceanographic research ships and, as such, will not impact the composition, distribution and management of research platforms. In fact, the increasing capability will probably, at least for the near term, serve as the impetus for vital at-sea experimental programs requiring the services of research ships.

Question 3. Secretary Lehman recently wrote a memorandum for the Chief of Naval Operations, saying "Because of the explosive growth in research and exploration in the world's oceans, and the rapidly increasing dependence of U.S. national security on the seas, it is now time for a major reinvigoration of Navy efforts in oceanography." Please comment on the effect of the new initiatives on the carrying out of marine research in this country. How will the other Federal funding agencies such as NOAA, NSF and EPA be affected? What will be the effect on data classification? How about ship reconstruction?

Answer. In July 1984, the Secretary of the Navy issued a policy statement to enhance and revitalize the Navy's efforts in oceanography. In addition, in April 1984, the Chief of Naval Operations issued a policy statement reaffirming the Navy's commitment to a strong and effective Naval oceanography program. Together, these policy statements are indicative of the Navy's current and future commitment to a strong and vigorous oceanographic program. While the Navy has traditionally maintained its commitment to a strong oceanography program, including oceanographic research, these policy statements have reemphasized the commitment and serve to strengthen the total oceanography program of the Navy. The Secretary of the Navy's policy identified 15 initiatives which are currently being implemented. These initiatives include a reorganization for the Office of the Oceanographer of the Navy, strengthening the career path and training for oceanographer designated naval officers, establishment of Secretary of the Navy research chairs in oceanography, establishment of Secretary of the Navy graduate fellowships in oceanography within the ONR graduate fellowship program, support for remote sensing, construction of a major new oceanographic research ship, development of a long-range Navy oceanographic ship construction plan, establishment of an Institute for Naval Oceanography with a focus on ocean modeling, and optimized management and use of Navy deep submergence assets.

The Secretary of the Navy's policy statement is a considered, balanced approach to strengthening the Navy's overall oceanography program. The initiatives are designed to provide emphasis in selected areas that will upgrade the Navy's effort to improve weapons system effectiveness by ensuring that the appropriate organization and resources are available in the near term. It is emphasized that these initiatives are designed to support Navy requirements, while at the same time providing leadership at the national level. Specific initiatives which will have an impact on and interact with national efforts involve ocean modeling, support for remote sensing, research ship construction, graduate fellowships, and optimized use of Navy deep submersible assets. Taken together these initiatives will broaden the scientific pool, upgrade the Navy's oceanographic research ship fleet, provide access to the Navy's 20,000-ft deep research vehicle *Sea Cliff* for research, and provide a focus for interagency efforts in remote sensing and ocean modeling.

While the Navy's ocean science program focuses on the unique needs of the Navy, it nonetheless contributes to national efforts in oceanographic research. Clearly, some of the new initiatives resulting from the Secretary of the Navy policy statement will contribute to and be coordinated with efforts of other federal agencies. For example, the Institute of Naval Oceanography emphasizes the development and transition of oceanographic models to support the operational Navy, such as for ASW operations, but will be closely coupled to other agency programs and will include participation by academic scientists and institutions. In addition, tentative plans also include the purchase of a super computer which will be accessible by communications link. Planning for this center is just underway and will not be completed for a number of months.

This ocean modeling effort will concentrate on time and space scales of importance to naval operations, such as mesoscale features and regional predictions, and will be an important complement to NSF's planned global circulation program. This initiative represents a balanced and integrated program in ocean modeling, remote sensing and experimental measurements. It will provide long-term benefits to the Navy and serve as a mechanism to integrate the various interests of NSF, NOAA, NASA and Navy. The potential provision of a super computer will also provide a necessary facility for ocean circulation and modeling research.

In the area of remote sensing, it is clear that NROSS will have a major impact on future research efforts; however, the Navy is also actively involved in demonstrating the utility of manned space flight for advancing our knowledge of the ocean. In June, NASA granted approval for the Navy to fly the first oceanographer on board the Space Shuttle. Mr. Paul Scully-Power, a civilian oceanographer with the Naval Underwater Systems Center, recently flew on shuttle mission 41-G launched on 5 October 1984. The Navy viewed this as a major opportunity to be shared by both the Navy and civilian oceanographic research communities. Admiral Mooney, as Chairman of the Navy Space Oceanography Committee, invited leading academic scientists to provide an input to the development of our observation plan for this flight and in formulating a long-range plan of ocean observation and measurement from space shuttle. We are interested in working with NASA, other federal agencies and academic institutions in our efforts to develop a cohesive long-range oceanographic research plan for manned space flight.

Two of the Secretary of the Navy's initiatives involve oceanographic ship construction. First, the Secretary has directed that Navy budget for the procurement of an oceanographic research ship to be utilized by the civilian academic research community with a target completion date of 1991. As a result, we have initiated action to design a major oceanographic research vessel which will have the speed, endurance and seakindliness to meet worldwide ocean research and data collection requirements year-round. We anticipate it will be a state-of-the-art research vessel capable of berthing about 30 scientists, operating in up to sea state 7, have dynamic station keeping, and have combined deck and laboratory space of over 7500 sq. ft. While both SWATH and monohull designs will be considered, serious consideration is being given to building the first large SWATH vessel in the U.S.

The other initiative involving ship construction requires the development of a long-range plan for replacement of the Navy operated survey and research ships, and the Navy owned research ships in the academic fleet. The objective of this program is to ensure that appropriate deep ocean ships are available to meet Navy operational and research needs.

These efforts affirm the Navy's commitment to the provision of adequate facilities within Navy and in the academic community for deep water oceanography. The Navy has always viewed its oceanographic ships to be national assets. As such, the new research vessel and future ships will upgrade the national capability and ensure a modern oceanographic fleet capable of global operations. The Navy efforts in ship construction and replacement are being coordinated completely with NSF, UNOLS and the Federal Oceanographic Fleet Coordination Council.

Many of the Secretary of the Navy's policy initiatives involve organizational and management actions to strengthen the Navy's oceanography program and ensure the provision of requisite facilities for research. As such, classification of data is not involved. These initiatives involving basic research will be conducted largely by the academic research community and will not involve classified programs. In the area of ocean modeling, mission specific models and products to support naval operations will not be available; however, the fundamental research results will be unclassified and it is anticipated that the basic models and validation data will be unclassified and can be shared to support agency needs and programs, and stimulate additional research.

Question 4. NOAA has stated in their testimony that the NOAA fleet will not need replacement until after the year 2000. Based on ONR participation with the planning of the Federal Oceanographic Fleet Coordination Council, how do you [illegible]aluate this claim?

[illegible]nswer. Without having conducted an engineering assessment of the NOAA ves[illegible]or a detailed analysis of NOAA requirements for ships, it is difficult to evaluate their claim. It is possible, however, to provide a general response which deals with ship replacement philosophy and factors which influence ship replacement decisions.

The factors which define ship obsolescence have no set values. They include material conditions, maintenance costs, habitability, and the capability to keep up with the changing needs of scientific requirements. The most commonly used measure is age. After a given number of years, the above factors will deteriorate to a point where it is no longer tolerable. The life span of a contemporary research ship is generally regarded to be 30 years. This can vary from 20–40 years depending on its construction, maintenance and service.

The average age of the NOAA fleet for all ships over 100 feet in length is about 17 years, with the vast majority of the NOAA fleet having been built and commissioned between 1962 and 1968. If the useful life of the NOAA fleet can be extended to after the year 2000, the average age will then be over 33 years at the time of earliest replacement. The useful service life a ship can be extended to this age or even 40 years with proper maintenance and mid-life modernization; however, NOAA wil[illegible]ced with the serious problem of block obsolescence of its fleet in the period 20[illegible].

In ord[illegible] a 40-year life, each of the ships would necessarily have to undergo a [illegible]ernization. Experience has shown that after approximately 20 years in se[illegible]s equipment can become obsolete, unsupportable or unreliable. This can occur through technological advance where a new standard is accepted by the majority of an industry and it is no longer profitable to support those customers who retain the old technology; through business failure of the original manufacturer; or through failure of the basic structure of a piece of equipment such as a package boiler or evaporator, which the manufacturer no longer supports. This obsolescence is a random, gradual process whose exact course is difficult to predict.

Scheduling of mid-life modernization is a NOAA action, but should probably occur for each ship at about 25 years of service. This date is flexible, but is estimated to be late enough that unsupportable items can be identified but early enough that sufficient ship life remains to amortize the cost. In addition, in order to minimize the cost impact, and time out of service, the mid-life modernization should be phased over a five to six-year period. For each mid-life modernization, a study should be conducted to identify obsolete and unsupportable equipment, and to identify cost effective upgrades of existing ships machinery and arrangements.

NOAA is participating along with the other federal agencies operating or funding ships in the ship replacement working group of the Federal Oceanographic Fleet Coordination Council (FOFCC). The FOFCC has encouraged its member agencies to initiate planning for ship replacement to avoid the problem of national block obsolescence. Under the auspices of the FOFCC, an interagency plan for ship replacement will be developed during the next year. As part of this effort, specific agency plans for replacement and ship modernization will be reviewed. In addition, actions will be taken to coordinate specific interests and to evaluate new vessel configurations and designs. As this new effort evolves, interagency agreements will be developed, where appropriate, on construction, cost sharing and vessel transfers, and the conduct of joint studies on ship design. I believe these actions will ensure cost effect and coordinated plans for the national oceanographic fleet.

NOAA will be contributing to this interagency effort. Decisions on replacement versus modernization of NOAA ships are appropriately left to NOAA, but will be factored in the overall plan. It is definitely feasible to extend the useful service life of a ship beyond 25 or 30 years, and other agencies, including the Navy, will also be evaluating this option. The final decision depends upon the condition of the individual ships or ships of a class, future requirements, design limitations which could limit productivity, assurance of mid-life modernization, and the pace of projected future operations. At this time, NOAA is in the best position to assess the condition of their fleet and its useful service life.

Question 5. ONR's support of both the Federal oceanographic fleet and of academic research in oceanography has decreased in the number of real dollars over the last ten years. Would you please briefly tell the Subcommittee why this has happened and the extent to which this change has been coordinated with the other Federal funding agencies? Was it assumed that NSF would proportionately increase their level of support? In the future, and as part of the Secretary's new 15-point initiative, do you see a change in this policy of Federal erosion of our support for basic research?

Answer. It is not true that ONR's support for academic research in oceanography has decreased in real dollars over the last ten years. A detailed answer to this question is required to provide the necessary insight into the Navy philosophy and support for ocean science and the facilities required to conduct the research effort. First, it is important to define ocean science in the Navy context. Ocean science in the Navy refers to that portion of the Navy's research (6.1) and exploratory development (6.2) technology base program that is devoted to all the disciplines of oceanography and atmospheric science. Therefore, the technology base ocean science program includes R&D in physical oceanography, ocean acoustics, biological and chemical oceanography, marine meteorology, marine geology and geophysics, remote sensing, ocean technology, mapping and charting, and environmental protection.

In FY 1984, Navy support for ocean science in basic research was approximately $80M, or about 27 percent of the Defense Research Sciences, Navy (PE 61153N) appropriation. Ocean science efforts in exploratory development amounted to about $20M, or over 4 percent of the total category 6.2N appropriation, about average among the 22 program elements in our 6.2 program. With an overall ocean science technology base program of $100M in FY 1984 out of $760M devoted to the entire Navy technology base, Navy is investing 13 percent of its technology base funding in this important area. Eighty percent of this amount supports basic research in ocean science.

Between FY 75 and FY 85, funding for the Navy's basic research ocean science program increased from about $32 million to about $85 million. In constant FY 75 dollars, this represents a real dollar increase of over $10 million. Therefore, it is not true that Navy support for research in oceanography has decreased during the past ten years. The program has overall kept pace with inflation and grown during an inflationary period.

The Navy is giving basic research the highest priority it can afford within the major Navy objectives of readiness, sustainability, modernization and force structure. We have launched a major effort to promote growth in the technology base. Real growth is 4 percent between FY 85 and 86 and is currently budgeted at 8 percent in research from FY 86 to 91. Congressional support is ensuring these modest increases in technology base funding will contribute to further needed growth in ocean science.

It is important, however, to keep support for ocean science in the proper perspective, relative to a balanced technology base. While the Navy is committed to a strong ocean science program, it is inappropriate to provide a disproportionate share to a single discipline or technology at the expense of other emerging technologies, or in lieu of maintaining a window in those other areas that promise opportunities for technological breakthrough.

Investment strategies for determining funding support for the ocean science program (as a percent of the total 6.1 dollars) reflects the results of a comprehensive planning process that was implemented in 1981 that balances naval needs with identification of new significant technological opportunities in a broad base of science disciplines and warfare areas. Consequently, decisions have been made to invest in a number of emerging technologies such as Materials Processing Science Base, Ultra Submicron Electronics, Solid Dielectrics, Energetic Materials, Cognitive Processes and Training, and Immunological Defense. In addition, the research program has had to help fill important gaps in the science base of the country through ONR's innovative Graduate Fellowship Program and DOD's University Instrumentation Programs, both of which are of direct and significant importance to naval operations, ocean science, and the future science base of the United States.

During the past few years, ONR took important steps to strengthen the credibility of the technology base. A structured, prioritized planning process was developed and implemented with emphasis on research and exploratory development areas that can potentially expedite scientific advances and their future delivery to the fleet. Greater emphasis has been placed on transition through the technology base towards fleet use and on the identification and support of promising high risk/high payoff programs.

The more focused efforts are concentrated in technology areas that are critical to long-term naval operational capability. In fact, ONR has structured more major projects in ocean science than in any discipline area. Nonetheless, ocean science is but one part of the total technology base and technological opportunities in other areas cannot be overlooked, such as computing technology, artificial intelligence and robotics, fiber optics, and millimeter wave devices and sensors. The maintenance of a vigorous Navy ocean science program can only be accomplished within the framework of a healthy overall basic research and exploratory development program.

The Navy has maintained a long-standing commitment as a major sponsor of oceanographic research in the academic community. It is important to note, however, that since the late 1960's there has been an evolutionary shift in funding for oceanographic research, and overall federal support for ocean science has increased significantly. Most notably, the role of the National Science Foundation in oceanographic research increased greatly during the 1970's. NSF thus emerged as a primary funding sponsor of academic oceanographic research. Today, a number of federal agencies, including NSF, are contributing to the national effort in marine research.

Along with the growth in federal support to ocean science, the Navy continued its commitment to this area and has retained its position as a leading supporter of ocean science. The combined Navy 6.1 and 6.2 program in ocean science, when viewed in terms of its relationship to the overall national effort, is still strong, it is coherent, it is balanced, it is at the forefront of research, and it focuses on unique Navy needs while also contributing to the national effort. On the national level, the Navy is working closely with the federal agencies and national organizations involved in oceanography to promote and ensure effective coordination of oceanic and atmospheric efforts. In addition, we are playing a leading role to improve the management of the national oceanographic research fleet—a vital national asset.

In conducting and implementing the ocean science technology base program, the Navy strives for a balance between the unique capabilities of universities, in-house Navy laboratories and centers, and contractors. In particular, we seek to combine the best qualities of basic research at universities with applied, sometimes classified work at Navy laboratories. In research, our philosophy is to obtain the best available scientists to work on Navy problems. It is recognized that many of the best scientists are located in academia and that universities and oceanographic institutions provide unique capabilities for performing specialized research. On the other hand, Navy in-house laboratories blend unclassified knowledge with classified applications to satisfy Navy needs.

While the performers of the Navy's technology base program include a wide range of academic institutions, Navy laboratories and Navy R&D centers, and Applied Research Laboratories, the academic community receives a major portion of funds available. This is particularly true with respect to the basic research program, where close to 60 percent of all dollars go to universities.

Of the $100 million total Navy technology base ocean science program, approximately 60 percent is spent in academia, 32 percent at Navy laboratories and the remaining 8 percent with private sector contractors. The vast majority of the work performed at academic and oceanographic institutions is basic research (6.1). Within the academic institutions, Woods Hole Oceanographic Institution and the Scripps Institution of Oceanography have been and continue to be mainstays of the contract research effort.

Other important contributors to the contract research program include Texas A&M, Lamont-Doherty Geological Observatory, Oregon State University, the University of Washington, the University of Hawaii, the University of Miami, Louisiana State University, the Massachusetts Institute of Technology, the University of Rhode Island, and Florida State University.

Finally, a number of small university programs around the country participate in the contract program and make an important contribution such as at the University of New Hampshire, Old Dominion University, Rice University, Jackson State University, the University of Maryland, Johns Hopkins University, and the University of Mississippi.

The current spread of funding support among all performers ensures a good balance between university conducted programs and in-house technology base efforts. For example, Navy R&D centers generally receive only a small percent of 6.1 funding in ocean science, but a majority of all work in 6.2 is performed in Navy laboratories. Exceptions within the Navy in-house laboratory community are the Naval Research Laboratory and the Naval Ocean Research and Development Activity, which are important performers as the Navy's corporate research activities in basic research.

The Naval Ocean R&D Activity (NORDA) was established in 1976 at Bay St. Louis, Mississippi in support of the Navy's plan to consolidate its oceanographic activities. Since [illegible], ONR has been working to make NORDA the Navy's primary center for in-house ocean science. Since its establishment, NORDA has grown significantly and in FY 81 received funding of over $6 million from category 6.1. The research program at NORDA complements the efforts conducted at universities, as does the research conducted at the Naval Research Laboratory. The emergence of NORDA makes it one of the three major performers in ocean science, along with the Woods Hole Oceanographic Institution and the Scripps Institution of Oceanography.

The Navy has a long history of support to oceanographic research and the facilities to conduct this research. Strong Navy support for oceanographic research has been provided to both Navy laboratories and universities by ONR for about 25 years. ONR can take credit for the initiation of ocean science programs at several major institutions and support to most of those which already existed.

Apart from the direct support of ocean science programs, the Navy also filled the gap in providing sea-going capabilities to academic institutions during the formative years. During the period from World War II to the mid-1970's, the Navy funded the construction or alternation of numerous ships for assignment to universities. In particular, during the 1960's and 1970's, the Navy designed and constructed seven research ships for charter to and operation by selected academic institutions. In addition, DSV ALVIN, its support ship LULU, and FLIP, a unique special purpose stable research platform, were all built under special research programs. These Navy-owned assets have been used to carry out research on behalf of many sponsors, including the Navy, the NSF and the Department of the Interior.

As a consequence of the evolutionary shift in funding support for university-operated ships which started in the late 1960's, the emergence of NSF as a primary funding agency for academic oceanographic research and inflationary pressure on ship operations, the percentage of Navy support for UNOLS ship support declined in the 1970's. Nonetheless, the Navy retained its long-standing commitment to funding a strong ocean science program by providing funding for ship time on a project basis. As a matter of policy, the Navy does not block fund ship operations, but rather is committed to providing funding on a project basis as an integral part of its support to academic institutions.

A few years ago, the material condition of the ships operated by the academic institutions became a matter of major concern. The costs of operating, maintaining and modernizing the academic fleet outpaced available funding support and inflation. The consequence was breakdowns, temporary ship lay-ups and deferred maintenance and modernization. In recognition of the importance of these vessels to Navy and national oceanography, and in view of the special obligation the Navy has for sustaining a healthy research program with adequate support for the academic fleet, ONR assumed the management responsibility for the seven Navy-owned academic ships and instituted a major ship upgrading and rehabilitation program.

These vessels are the *Conrad*, operated by Lamont-Doherty Geological Observatory; *Knorr*, operated by Woods Hole Oceanographic Institution; *Melville* and *Washington*, operated by Scripps Institution of Oceanography; *Thompson*, operated by the University of Washington, *Mauna Wave*, operated by the University of Hawaii, and *Gyre*, operated by Texas A&M University.

In the past four years, ONR has committed over $11 million to correct accumulated deficiencies, for mid-life refits and rehabilitation, and for ship modernization. In addition, in recent years the Navy has also increased its funding support for ship operations. As a result of this major commitment, we feel that the academic community and the Navy have the assets required to conduct "blue-water" oceanography on a global basis. In addition, we are committed to continued maintenance of these vessels to preserve our investment and ensure their availability for naval oceanography.

I believe this detailed response to the question shows the Navy's commitment to a strong ocean science research program and dispels the notion that the Navy effort has weakened in recent years. The Navy's ocean science program will continue to build on past progress while also growing in new directions, reflecting new needs. The actions the Navy has taken with respect to the academic fleet reflects a major contribution toward restoring the vitality of the university-operated research fleet. It is unrealistic to expect a massive infusion of funding support for research ship operations beyond that required to satisfy our needs.

The Secretary of the Navy policy initiatives are clearly indicative of the Navy's commitment to ocean science and to our continued leadership at the national level. The maintenance of a vigorous Navy ocean science program can only be accomplished within the framework of a healthy basic research and exploratory development program. The Navy has programmed real growth in the future for the technology base, growth which will provide the resources necessary to undertake a variety of new initiatives in addition to those [illegible] Secretary of the Navy. With congressional support for future budgets, we can collectively strengthen the technology base and expand our ocean science and other efforts to support the needs of the Navy and contribute to national efforts in oceanography.

Response to Questions of Mr. Pritchard by EPA

Questions. There was serious concern expressed during the first panel that the upcoming studies on Puget Sound, Narragansett Bay, Long Island Sound, and Buzzards Bay might not increase our long-term understanding of these estuarine systems. Would you please describe the purpose of these studies, what EPA has done to date, and how the results will be used? How will the findings be used in the regulatory process? Will the knowledge gained on each of these four systems be transferable to other estuaries and, if so, to what extent?

Responses. The goal or purpose of the studies on the subject Bays is to protect human health and restore, enhance, and maintain a biologically productive estuarine environment which is compatible with attainable uses. The EPA response to this goal is to develop a cost-effective approach to the level of understanding of these systems that is required to develop pollution control programs.

Major activities to date include the initiation and development of a research, monitoring, assessment and environmental control program for these Bays. On October 1, 1984, the new Office of Marine and Estuarine Protection was formally established in the Office of Water. This office, as part of its responsibilities, will provide policy guidance and management assistance for implementation of the goals and objectives of the Bays' Program.

The program will be a significant contribution to the long-term understanding of the environmental trends in these estuaries. But the charge to the EPA is relatively restrictive and the focus on four separate estuaries at the level of funding constrains the scope of any research program on these large estuarine systems.

Several substantive discussions for planning purposes have been held with our Regional personnel in Regions I, II and X, their respective State counter-parts, public interest groups, and officials from the Headquarters of the National Oceanic and Atmospheric Administration (NOAA). These meetings have led to the development of management strategies and plans for the respective Bays. These planning documents are near final form for Puget Sound. We anticipate receiving draft planning reports for Narragansett Bay and Long Island Sound by January 1, 1985. A similar set of planning documents for Buzzards Bay should be available by mid-December 1984.

We describe the status of the Puget Sound planning effort in more detail to indicate the Agency's approach to these studies and cleanup efforts. The Puget Sound project includes the formation of the Puget Sound Project Office which will be staffed by State and EPA employees who will provide day-to-day management of the Program. This action was jointly announced on August 29, 1984 by the Administrator of EPA and the Governor of the State of Washington. The management strategy defines the conceptual framework of the project. For example, it describes the known pollution problems and ways to assess if other water quality problems exist, a statement of environmental goals and objectives for the Sound, guiding principles, approaches for effective coordination and reporting of work activities and management action. In addition, the strategy outlines the roles and responsibilities of a proposed management structure, i.e., a policy group, a steering committee, citizens involvement committee and technical advisory committee. Efforts at coordination include the involvement in planning by the EPA Office of Research and Development, the Headquarters and Laboratory personnel of NOAA, the Corps of Engineers, Washington State Department of Ecology, Seattle Metro, the Puget Ground Water Quality Authority and the Puget Sound Alliance, a public interest group. The approach described here for Puget Sound is being carried out for the remaining three Bays.

Results of the Program will be used to improve our understanding of the linkages between pollutant loadings and their environmental characterization and environmental transport, fate and effects in the respective Bays. This knowledge is essential to the development of a scientific basis for control options and waste placement. Such knowledge will assist in the development of cost-effective and environmentally meaningful monitoring plans which are a principal element in assessing the future environmental status, trends and control program effectiveness. It is appropriate to point out that in some cases we may need to proceed with management and control decisions before a particular scientific uncertainty is completely resolved because it may require a fundamental increase in our knowledge that may be beyond our foreseeable resources or available time. In other cases, we may have adequate information to initiate environmental controls.

The findings will be used in the regulatory process to improve the scientific basis and public acceptance of permit actions, the development and refinement of site-specific water quality criteria and standards, compliance and trend monitoring and waste load allocation, i.e., setting the maximum daily load of a pollutant. Where single or a small number of pollutants cannot be associated with toxicity, then the Agency's toxicity-based pollution policy will be implemented.

It is the full intent of the Agency to transfer knowledge gained on each of these four systems to other estuaries. Just as many elements of the present program draw on experience and knowledge gained in the Chesapeake Bay Program including examples from managerial and scientific efforts, the Agency will apply such information where appropriate to other estuarine systems. The extent of the transfer will depend on the nature of the pollutants, their patterns of loadings, the present status and nature of the receiving water and resources available to carry out such activities. With these conditions and any existing scientific uncertainties in mind, the Agency will carry out the transfer of knowledge gained in the present program to the maximum extent required to protect the public health and welfare.

RESPONSE TO QUESTIONS OF MR. PRITCHARD BY DR. FERRIS WEBSTER, CHAIRMAN, UNOLS

Question 1. What is being done on both a national and an international scale to anticipate the problems for data management that the exponential increase in satellite data will cause in the next decade? What is being done to ensure quality control and format standardization?

Response. As you say, there will likely be an exponential increase in oceanic data from satellites in the next decade. Most of this will be associated with satellite sensors that are expected to be launched around 1990. Though I am not familiar with all the plans that are being made for satellite data management, I can respond with respect to the uses to be made by the U.S. components of the World Climate Research Program (WCRP). Two of these components are those for the program on the Interannual Variability of the Tropical Ocean and Global Atmosphere (TOGA) and for the World Ocean Circulation Experiment (WOCE). The National Academy of Sciences Panels for WOCE and TOGA are jointly sponsoring a data management subpanel (of which I am the chairman). The two Panels are starting with the assumption that a common data management system may meet the needs of both programs.

In developing plans for ocean data management for the WCRP, the data management subpanel is giving emphasis to ease of access by users, possibly by using a highly distributed system that takes advantage of advances in communication networks and microprocessing. We envision many linked data centers, with oceanographers being actively involved in the development of data products.

The data management system is receiving considerable attention from the subpanel. Recent experience has shown that effective data management depends principally on the system developed and on the institutional arrangements to implement it, rather than simply on hardware or technology. The traditional concerns of quality assurance and standardization of formats are also receiving attention. Merging new types of data from satellites with conventional oceanographic data is another topic of concern.

Question 2. I understand that you have taken a look in trends in the level of Federal research support for oceanographic research over the years. Would you supply these figures for the record, being sure to include a description of how you arrive at these figures? Would you comment on the significance of these trends, and hazard a prediction as to the health of the U.S. oceanographic research capability in the next ten to fifteen years? What do you think should be done?

Response. I have attached the figures on funding for "oceanographic research" that I have taken from the Federal Ocean Program reports, now published by the Committee on Atmospheres and Oceans of the Federal Coordinating Council for Science, Engineering and Technology. I have not done anything with the figures—they are exactly as reported in federal documents. However, they should be used with care, since there may be year-to-year changes in how each agency defines "oceanographic research". An example of this can be seen between 1981 and 1982, where the Department of Defense (DoD) changed its categorization.

On the right-hand side of the table, I have deflated the data with the Consumer Price Index (C.P.I.), to give the budgets in constant 1967 dollars. These C.P.I. values, and estimates for 1984 and 1985, were provided by Prof. Eleanor Craig of the Economics Department at the University of Delaware.

It is evident that federal support of oceanographic research, as defined here, has not kept pace with inflation over the past decade. There have been particularly strong decreases in the Department of Commerce (i.e., NOAA). In addition to individual agency declines, over overall national oceanographic research capability has been slowly decreasing. If this is deliberate, I would like to see the reasoning made public. If it is not deliberate, but arises from ineffective and uncoordinated national policies, more attention should be directed to the problem.

There is no reason that the decline in the national oceanographic research effort should continue over the next ten to fifteen years. It could be quickly reversed. First, we should make more effort to define the situation and thereby to analyze its causes. This would likely be a prerequisite to taking action to develop a conscious policy. A basis for such a policy might be a restatement of oceanographic research priorities as proposed at your hearings. I believe that the oceanographic research community and Congress have major roles to play.

Question 3. In your recent study for the National Research Council on "An Ocean Climate Research Strategy" you state that there is "so far no U.S. commitment to establishing long-term ocean climate monitoring". How can these be achieved? What implication will it have on funding agencies, specifically NSF, NOAA, ONR, and EPA?

Response. Since I wrote the report An Ocean Climate Research Strategy, I have been encouraged by ocean monitoring developments within the National Ocean Service (NOS) of NOAA. Under Paul Wolff's leadership, NOS seems to be making an effort to develop an ocean monitoring program. As I pointed out in the report, this is an area that is a natural one for NOS, in analogy with the atmospheric monitoring maintained by the National Weather Service. It should probably not be a function of NSF or ONR, since it is not primarily research; the kind of thing that is needed is broader than what EPA might do. NASA might lead in a demonstration of feasibility of satellite monitoring, but it should likely be taken over by an operational agency—again, NOS.

I have recently seen a document entitled The National Ocean Service Program, prepared within NOS. I am heartened by the progress they seem to be making in developing ocean services, including ocean monitoring for climate, though I am not close enough to the program to be aware of the details.

Question 4. Are long-term weather predictions an ultimate goal for the World Climate Research program? Do you feel it is achievable? What are the necessary resources? If our country established the goal of being able to predict natural weather variations one year in advance, what level of effort would be required to achieve this goal within ten years?

Response. Yes, long-term weather predictions are a goal of the WCRP, as are long-range climate predictions. The feasibility of these predictions is a scientific question to which the answer is being sought. With advances in oceanic and atmospheric modelling and computers, and with the El Niño phenomenon as a stimulus, I am optimistic that the answer will be positive, and that we will soon have enough understanding to being some attempts at interseasonal climate prediction.

Though I am not sure that predicting climatic variability one year in advance is feasible, I expect the TOGA program to make significant progress in developing the scientific basis for season-in-advance climate predictions. Congress has so far supported the TOGA program at an appropriate level of effort. The WOCE program, now being developed, will look at longer-term climate variability than TOGA. I hope that Congress will be favorably inclined towards WOCE.

Question 5. The Joint Oceanographic Institutions, Inc., has recently completed a study on the use of satellites in the study of oceanography during the next ten years. How is the increasing remote sensing capability being factored into the overall U.S. oceanographic research effort? What are the implications on the composition, distribution, and management of research platforms?

Response. If current plans for satellites come to pass, towards the end of this decade we should see a substantial increase in our capability to study the ocean. There have been numerous studies of what satellite-borne sensors can do for oceanography, but as far as I know, none of them has examined the impact they will have on the overall U.S. oceanographic research effort. In particular, there is considerable speculation but little substance on which to determine the impact of satellites on the composition, distribution, and management of research platforms. These speculations range from the possibility that satellites may replace some of the functions of research ships to the possibility that the knowledge of the ocean that satellites will provide could increase the need for conventional research ships.

UNOLS briefly discussed the topic at its recent semiannual meeting. It was agreed that this subject will receive fuller attention at a future meeting. So far, UNOLS has been slow to take specific action because of uncertainty about what satellite systems will be available over the next decade and what their oceanographic capabilites will be. With the uncertainty, it is difficult to establish concrete recommendations.

I hope these answers have been responsive and helpful. I would be pleased to respond further.

"Oceanography" funding in Federal Ocean Program

Fiscal year	Oceanography total	NSF	DoD	DoC	CPI %	In 1967 dollars: Oceano	NSF	DoD	DoC
67	$61.5	$24.8	$28.6		$100	$61.50	$24.80	$28.60	
68	78.1	38.3	30.5		104.2	74.95	36.76	29.27	
69	78.4	34.9	34.3		109.8	71.40	31.79	31.24	
70	78.4	30.3	33.2		116.3	67.41	26.05	28.55	
71	101.5	49.4	32.1	$19.7	121.3	83.68	40.73	26.46	$16.24
72	119.4	65.7	30	20.5	125.3	95.29	52.43	23.94	16.36
73	109.9	57.3	27.3	21.5	133.1	82.57	43.05	20.51	16.15
74	116.1	61.1	28.4	19.7	147.7	78.61	41.37	19.23	13.34
75	124.1	69.2	27.7	19.5	161.2	76.99	42.93	17.18	12.10
76	128.9	66.7	31.8	19.8	170.5	75.60	39.12	18.65	11.61
77	144.6	73.8	31.8	23.5	181.5	79.67	40.66	17.52	12.95
78	157.6	78.9	37	26.9	195.4	80.66	40.38	18.94	13.77
79	172.9	88.8	40.4	28.8	217.4	79.53	40.85	18.58	13.25
80	206.1	97.5	45.5	40.2	246.8	[illegible].51	39.51	18.44	16.29
81	218.4	95	53.8	42.9	272.4	80.18	34.88	19.75	15.75
82	170.1	104.9	18.1	20.7	289.1	58.84	36.29	6.26	7.16
83	176.4	107.8	20.1	20.5	298.4	59.12	36.13	6.74	6.87
84	188.7	127.8	13.5	21.1	312.4	60.40	40.91	4.32	6.75
85	190.3	138.5	20.9		331.2	57.46	41.82	6.31	0.00

JOINT OCEANOGRAPHIC INSITUTIONS, INC.,
Washington, DC, November 3, 1984.

Hon JOEL PRITCHARD,
House of Representatives,
Committee on Merchant Marine and Fisheries,
Washington, DC.

DEAR MR. PRITCHARD: Thank you for your letter of October 12, 1984. It was a pleasure for me to appear before the Subcommittee on Oceanography on September 26, and I hope that the hearings provided the information needed by the Subcommittee.

I agree with your observations about the way in which priorities are established, coordinated, and followed through by the Federal agencies responsible for funding marine research. On the one hand, the plurality of agencies and funding mechanisms involved is a strength for our community, allowing diversity and different approaches. On the other hand, we need better communications and coordination among those federal agencies, the academic community, and industry.

I hope that the next decade will see continued and increased support for oceanography within the Federal Government and the emergence of NOAA as a scientific agency, taking its proper role in civilian oceanography. I also hope that other organizations such as JOI, UNOLS, and others representing the academic community can play a stronger role in developing priorities and helping to see that these priorities are met.

One point is of specific importance. We anticipate major scientific advances in the next decade in our field, but these advances will be crucially dependent on adequate support for new technology. Specifically, the use of supercomputers and of satellite

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measurements is essential for the advancement of oceanography to a predictive science. Thus we need commitments for the use of these technologies for oceanographers and for the support and training of new personnel in oceanography.

Specific budget items of importance for FY 1986 include the oceanographic components of the World Climate Research Program (TOGA and WOCE—see question 4 below), and NASA's ocean satellite TOPEX (see question 2 below).

To answer your specific questions:

1. "Is the current process used in setting budget priorities within the Federal funding agencies for oceanographic research adequate? If not, what suggestions would you make to lead to a more effective mechanism?"

As you know, there are a number of federal agencies involved in funding oceanographic research. In the National Science Foundation, the Office of Naval Research, NASA, and most other agencies of relevance, the budget priorities are determined by a fair and competitive process. Moreover, the oceanographic priorities that are established in these agencies seem to survive in an identifiable way through the entire budget process through OMB and the Congress.

It is more difficult for our community to follow the budget process for NOAA. For example, in spite of the fact that the agency, the marine research community, and outside groups like the Heritage Foundation have continually identified the Sea Grant program as a high priority, that line item does not survive in the Administration budget. Other marine research has similar problems.

More effective coordination of marine research could come either through FCCSET and its subcommittees or through a national office whose specific task would be the coordination of Federal marine research budgets. The National Climate Program Office comes to mind as an example. It would also be helpful if budget cross cuts were made both by OMB and by the Congressional Budget Office; for example, the same examiners could study the marine programs for NSF, NASA, the Navy and NOAA before final budget recommendations are made.

2. "How is the increasing U.S. remote sensing capability being factored into the overall U.S. oceanographic research effort? What are the implications on the composition, distribution, and management of research platforms?"

There are major efforts now going on in both the oceanographic community and in the federal agencies to design new programs based on the developing remote sensing capabilities from satellites and aircraft. Satellites now in orbit measure oceanic properties important to our understanding, like sea surface temperature, and new satellites are planned to measure winds (the Navy's N-ROSS), currents (NASA's TOPEX), and biological productivity of the ocean (the Ocean Color Imager). This new technology is highly important, not just for the ocean, but for the earth in general. Therefore it is essential that the new earth-looking satellites be included in the budgets as they are recommended by the agencies, and that those long-lead-time items such as instrument development, data handling and communications links be funded now so that we are ready when the satellites fly in the early 1990's.

As the satellites bring in new information, there will be an increased demand for measurements in the ocean itself. This will bring a demand for research platforms including ships, moored and drifting buoys, and bottom-mounted platforms. Funds must be available for meeting this demand.

3. "JOI Inc. is responsible for providing the scientific planning and operations management for the new Ocean Drilling Program. Do you feel that the institutional structure of JOI could be used as a model and applied to other large-scale research projects?"

The institutional structure of JOI allows the collective capability of individual institutions to be brought to bear on large oceanographic research projects. This arrangement has been very effective in developing community consensus in marine geology and geophysics for use of new technology like deep-sea ocean drilling and seismic multichannel capability for remotely measuring the sea floor. The overall structure of the management of the Ocean Drilling Program has also been successful internationally: currently we have five non-U.S. partners contributing to the program, and all funds are managed through JOI Inc. Therefore this type of organization could well be used by other large projects.

JOI Inc. is supporting the planning for oceanography from satellites, including both measurement efforts and the data management needs. We expect that this effort will be a major one in the future, and we are using our corporate facilities to help with this program and others where appropriate.

4. "It is now acknowledged that the ocean plays a major role in world climate. Are long-term weather predictions an ultimate goal of the World Climate Research Program? Do you believe that such predictions are, and do you have any ball park estimates of the potential economic benefits of such an improved capability? What

are the necessary resources? Are the funding agencies taking into account these needs? If our country established the goal of being able to predict natural weather variations one year in advance, what level of effort would be required to achieve this goal within ten years?"

The main goals of the World Climate Research Program are to determine to what extent climate can be predicted and the extent of man's influence on climate. These main goals have been divided into three specific objectives: to improve prediction of weather for periods up to two months, to improve prediction year-to-year changes in climate like the El-Nino, and to assess the response of climate to changes in carbon dioxide and volcano emissions. Each of these specific objectives requires a focused research program, and they all involve measurements and understanding of the ocean.

A growing body of evidence is emerging from observations and theoretical studies indicating that a substantial part of world-wide climatic changes are related to year-to-year variations in the tropical ocean and the overlying atmosphere. As a consequence, the World Climate Research Program has been planning a Tropical Oceans and Global Atmosphere program (TOGA) that will study the coupled variations of the global atmosphere together with the variations of the tropical Atlantic, Pacific, and Indian Oceans for the purpose of predicting the year-to-year changes of the atmosphere. This program will start in 1985; the lead agency is NOAA. It is essential that this program receive adequate funding if we are to make advances in this important national program.

At the same time, we need to be concerned with man's effect on the climate, such as increasing CO_2. Because it is a very large heat reservoir, the world ocean could slow down any warming trend induced by excess CO_2 and delay atmospheric warming by as much as several decades. Moreover, the world ocean absorbs a large fraction of the incoming solar energy, transports heat globally, and is the main source of moisture for the global hydrological cycle. To understand these processes for better prediction of long-term changes, we need to understand the ocean circulation. For that reason, the World Climate Research Program has also proposed the World Ocean Circulation Experiment (WOCE) to measure circulation and mixing in the ocean on a global scale. NSF is the lead agency for WOCE. This program must also receive adequate funding if we are to make adequate climate predictions.

Key to each of these climate programs is the use of new technology—specifically satellite measurements of the ocean and supercomputers for data analysis and modeling. The Navy's NROSS satellite, now in the FY 1985 budget, will provide crucial data on the winds in the tropical regions for TOGA. NASA's TOPEX satellite, now under review in the FY 1986 budget, is crucial to the global measurements required for WOCE. As documented in the JOI report on Oceanography from Space, the two satellites must fly at the same time so that we can measure the winds that cause the currents (NROSS) and the currents themselves (TOPEX). NROSS is scheduled for flight in 1989. Therefore it is crucial that TOPEX be funded in FY 1986 so that it can fly at the same time. The potential economic benefits of improved prediction are so great that the costs of the new technology can easily be justified.

The economic benefits of improved prediction have been estimated by many different groups, including the National Weather Service. A 1972 study showed total weather related losses to be over $27 billion in 1983 dollars for the U.S. Of this, over $1.1 billion could have been protected if perfect forecasts had been available and used for a net economic gain after the costs of protection of about $1.6 billion. The global impact of the 1982–1983 El Nino is estimated to be almost $10 billion. Even if perfect forecasts are not available, it is clear that substantial sums of money are involved with every improvement in forecasting. There is a real economic gain to be achieved, one that should be considered when the NOAA budget is under review.

In my view, the funding agencies are now taking into account the needs for new resources to provide improved forecasts. NOAA, NASA, NSF, DOD, and others have all identified the needs for global observations and use of supercomputers for better knowledge and prediction. The National Climate Office has prepared a series of reports identifying the necessary resources and the level of effort needed to meet goals such as the one mentioned as predicting natural weather variations one year in advance.

5. "You state in your testimony that the ocean sciences in this country are suffering from a deteriorating infrastructure. Would you please explain exactly what this means, and how JOI has documented it? What else is necessary besides money to correct this situation? What will happen if nothing is done?"

Infrastructure can be broadly defined as the tools we need to carry out our research and to teach our students. Thus infrastructure includes equipment in laboratories and on board ships, facilities that provide measurement techniques, buildings for laboratories and teaching, and highly skilled technical personnel. We also include support for training of new scientists in this growing field. Since the ten institutions represented by JOI receive the majority of the research dollars allocated to ocean sciences by the NSF, the JOI Board of Governors is familiar with the needs in this area. To document the needs, the Board made a survey of each of the JOI institutions, and contacted a number of other institutions to ensure a broad input.

We need funds to correct the infrastructure problem. In addition to funds, we need a long-term commitment from the Federal Government that oceanography will be supported in fair relation to its contribution to national needs. With this long term commitment we will be able to move to the future with the necessary new technology and with committed scientists and engineers to attack important national problems. Without this commitment and new funds, we will find that many important problems will go unsolved, and many will be taken over by other nations. But since the U.S. is the major contributor to international ocean science, it is likely that many of these efforts will be too small to be effective, and significant opportunities will be lost.

6. "Would you expand upon your suggestion regarding national research facilities? Who would decide where they should be and what they should include? How should they be funded? How would these facilities differ from our existing oceanographic laboratories around the country?"

As we move towards more and more complex technology, we need to consider shared use for cost-effectiveness. Our academic fleet is already managed by a national organization, UNOLS. The deep sea drilling vessels have been managed with the advice of an international group, Joint Oceanographic Institutions for Deep Earth Sampling. In each case, the oceanographic community has identified the need and used its coordinating mechanisms, UNOLS and JOI, to help organize the appropriate administrative mechanism. I expect that the same would be the case for new facilities, and that these new facilities would be funded by the appropriate federal agency or group of agencies.

I appreciate the opportunity to expand on the discussion at the Hearing, and I would be pleased to provide further information as required. I look forward to working with the Congress in the future to help to develop support for oceanography.

Yours sincerely,

D. JAMES BAKER, *President.*

WOODS HOLE OCEANOGRAPHIC INSTITUTION,
Woods Hole, MA, October 19, 1984.

Hon. JOEL PRITCHARD,
Committee on Merchant Marine and Fisheries,
House of Representatives,
Washington, DC.

DEAR MR. PRITCHARD: Thank you very much for your kind note concerning the recent testimony on marine research before the House Subcommittee on Oceanography hearings. I share your opinion that this meeting provided an important opportunity for looking at the status of marine research in federal government and elsewhere, and for exploring further opportunities.

The establishment of priorities within the marine community has always been a problem. During the question period I attributed this, in part, to the diversity within the profession—biologists, chemists, geologists, etc.—and, in part, to the typical specialities within these disciplines. Members of the various disciplines often feel compelled to support their constituencies (not unlike Congress) and/or are naive or unconcerned about the needs or goals of other fields. I personally feel that one way around this is by the manner in which the national program or goal is stated or presented. In other words, if the Government knew the priorities (not just for a year, but longer), the marine scientific community could develop the research protocols and necessary priorities within this national effort. If the choice of national goals is left to the marine community, there would be a multiplicity of choices. But some choices, like improving our sea-going capabilities, would come near the top of most lists. The process would probably work best by avoiding the discipline-oriented type of approach.

Your letter posed two specific questions, and I would like to respond as best I can. The first concerned possible locations for the proposed Office of International Marine Science Cooperation. Basically, there are three major possibilities for the location and responsibility of the Office. First is within the government itself. Here, as perhaps with any other category, there is a possibility of the Office being "trapped" by a government agency. Past experience indicates that government agencies have not worked well cooperatively and have tended to dominate opportunities. If the Office were within the State Department, perhaps one of the more neutral agencies, it could be perceived (by foreign governments) as an Office directly related to the U.S. government and its foreign policy, or even be mistaken as a source of funds. Wherever the Office is located, that close liaision with the State Department is imperative; but, I don't believe State would be the best place for its location. Other government possibilities include the National Science Foundation, yet they do not seem very enthusiastic about such an Office, and again it could be considered as a funding opportunity. In addition, NSF doesn't generally consider applied research, although that could be a key priority of the Office. The National Oceanic and Atmospheric Administration and the Office of Naval Research are other possibilities. Both have their own competent international programs. Again, though, these could be seen as being representative of only one part of the U.S. community.

The second category would be within an independent organization. Three occur to me. (1) University-National Oceanographic Laboratory System (UNOLS): I have discussed this Office with UNOLS. It could be a natural operation for them, yet UNOLS is mainly represented by ship operators and those individuals at institutions who run ship operations. Again, not the best purview for the development of the scientific program, although close cooperation with this group would also be valuable. (2) Joint Oceanographic Institutions (JOI, Inc.): Again here, although a viable group, they represent only a small portion of the U.S. oceanographic community (the largest six or seven institutions). (3) Finally, an independent organization, such as the National Academy of Sciences: There is some appeal here. However, the National Academy for all its wisdom is still really a "volunteer organization" with supporting staff, and does tend to move at a rather slow pace.

The third category is within an oceanographic institution. Oceanographic institutions, out of all these groups, have shown historically the best record of working together when mutual interests are involved. Foreign programs could involve scientists from several countries, as well as from various U.S. organizations. I believe oceanographic institutions would have the best possibility of drawing such an audience. Clearly, if the Office was located at an oceanographic institution or in an area adjacent to an oceanographic institution, it must be perceived as being fair. The particular institution should not receive any advantage in its international activities. An advisory group could help here. Perhaps one could visualize, for a model, the recently established National Coastal Resources Research and Development Institute, as proposed in Public Law 84-364, at Oregon State University. I would suggest some differences if the proposed Office were established this way, such as being governed by a broader group of individuals. In any case, it is clear that such an effort would be an experiment, and although there may be no perfect location, we should opt for the one with the best chance of success.

Your second question concerned the Red Sea brine area, the status of what is being done there, and the economic potential of this resource. I enclose two papers that may be of some interest to you. The economic potential of this resource, of course, is hard to estimate. In situ values have ranged, as far as I know, from about $2.4 billion to as high as $8.6 billion.

Interestingly enough, the group that estimated the higher value thought it was uneconomic to mine; the group with the lower value felt is was. As I am sure you and the committee will appreciate, the potential value of any resource on the sea floor may have little to do with the realities of the cost of raising the resource, beautification of it and eventual economic distribution. It is my understanding that the Germans and Saudi Arbians with assistance from the French government have developed processes for raising the material and refining it. They have "solved" environmental problems and are close to actually starting the process of mining the Red Sea deposits. This activity, in some respects, saddens me since the U.S. was the key player in some of the early discoveries of this deposit, and had (and still has) the technology to exploit it. Nevertheless, this will probably be the first important mineral deposit raised from the deep sea (about 6,000 feet). The Red Sea sulfides should not, however, be confused with the polymetallic sulfide deposits that we currently hear so much about. The Red Sea brines are approximately 95% water and really are a very fluid mud. We also know quite a bit about the distribution of this deposit in three dimensions, where as polymetallic sulfides are relatively hard rocks about which more research needs to be done in order to know about the width, depth and quality of the deposit. However, both are important scientific discoveries.

Thank you again for the opportunity to participate in this meeting and to communicate my thoughts to you. I hope I have answered some of your questions.

Sincerely,

DAVID A. ROSS,
Director of the Marine Policy and Ocean Management Program.

UNIVERSITY OF WASHINGTON,
Seattle, WA, October 18, 1984.

Hon. JOEL PRITCHARD,
U.S. House of Representatives,
Committee on Merchant Marine and Fisheries,
Washington, DC.

DEAR MR. PRITCHARD: Thank you for your letter of October 12, 1984. I appreciated the opportunity to appear before the Subcommittee on Oceanography on September 26, and to respond to your questions.

The point in your letter about the ad hoc establishment and execution of research priorities for marine science in the U.S. is well taken. This problem has many roots: too few resources chasing too many problems; too many agencies protecting turf rather than acting in the national interest; and a real reluctance by all branches of the federal establishment to make 5 to 10 year commitments to support well-designed projects that address specific problems. Most of the simple problems have been solved. Those remaining are not likely to be solved by short-term, "fad-of-the-year" injections of funds, even lots of funds!

What to do? Firstly, the agencies should make better use of existing planning mechanisms and procedures. OMB requires that all agencies prepare long-range (10-year) budget estimates. Yet rarely are these estimates based on well thought out long-range plans, or sensible coordination with sister agencies.

Secondly, disinterested "high powered" outside review committees still exist in most agencies (despite the efforts of the last two administrations). These committees should be charged with playing a stronger role in reviewing agency research priorities, their execution, and digestion.

Thirdly, the National Academy of Sciences was established by the U.S. Government to give it expert scientific advice. Too many agencies fail to make effective use of this organization for assessing their long-term priorities and research performances.

To get down to your three specific questions:

1. "As technology drives oceanographic research into a new era of data collection, the ensuing problems for data management are enormous. Not only are new kinds of data being generated, but it is being produced in vast quantities. What is being done to ensure data quality and format standardization? Will it be adequate in the future? What are your recommendations in this area?"

The ability to scan, select and combine very large data sets is crucial if we are to fully exploit satellite observations of the ocean. This need was recognized early by JOI Inc's Satellite Committee, which is working with NASA to develop the specifications for an effective data-management system. This is only the first step however. The responsibility for operating an accessible bank of quality-controlled data rests, unequivocally, with NOAA. They are the civilian ocean agency. Their performance to date has been discouraging; they are set up to handle data generated by the International Geophysical Year of three decades ago, but cannot deal with CTD or current meter records, for example, of more recent vintage. Whether the problem is resources or institutional motivation is unclear. In either case, this problem must be resolved within the next couple of years if the taxpayers are not to be cheated of a fair return on their future scientific investments.

2. "As Dean of a large college involved in marine research, what do you see as the delineation of roles between the Federal and academic effort on oceanographic research? Is there an existing forum for looking at this problem? What do you recommend? Specifically, what do you see as an appropriate role for NOAA in marine research and monitoring?"

A look at history shows that academic oceanographic institutions excel at education and the development of innovative concepts and observational techniques. They do less well at measuring long-range trends, at systematic mapping of the oceans, at maintaining records and data bases that are readily available to a wide public, and at responding to requests for information on or explanations for scientific phenomena. These latter areas are exactly the ones that federal laboratories and offices can handle very well. They can create institutional mechanisms to ensure a continuity of operation that no individual faculty member (the functional "unit" in academia) can match.

When these roles are reversed, oceanographic research suffers. The academician who has to maintain, read and preserve tide gage records, for example, is doing less teaching and creative thinking. The NOAA employee who is expending a large effort on pure research on Gorda Ridge hot springs is not mapping the EEZ very effectively.

This problem is well recognized. NOAA's upper management is well aware of its optimal role in oceanographic research. The problem develops further down the line: too many labs whose raison d'etre has vanished or become obsolete, yet which persist because of their politically adept directors; too many NOAA scientists who view their role as untrammeled research, rather than addressing the agency's mission needs; too little effort to involve academia in those basic research problems which can be addressed so effectively by bright graduate students and outstanding faculty.

By comparison with other mission agencies, NOAA's interaction with academic research programs is weak. I believe that this has hurt NOAA in recent years. Unlike NSF and NASA (which put the bulk of their funds into academic research) NOAA is not perceived as a major player in the nation's basic research effort, hence has not received much budgetary support from OMB. Separation of NOAA from Commerce (which is not a research-oriented department), appointment of a well-qualified, strong administrator, and restructuring of the agency to recognize its distinct service and research support roles could solve the problem. I do not believe that the topic needs more discussion. Some action is called for!

3. "The Board on Ocean Science Policy (BOSP) of the National Research Council is currently undertaking a study entitled 'Oceans 2000.' Will there be implications for the Federal funding agencies, and if so, what will they be?"

The BOSP/"Oceans 2000" study will report on scientific opportunities for the rest of the century and the infrastructure that will be needed to take advantage of them. Because these opportunities will involve satellite observations, long-term oceanic observations, data management, and the deployment of seagoing facilities from both civilian and military agencies, "Oceans 2000" will have funding implications for both the agencies involved and for academia. These implications will need to be thrashed out through interagency discussions on the federal oceanographic fleet, through studies by UNOLS and JOI, and by the developing mission needs of the various agencies, as well as through the "Oceans 2000" recommendations.

The success of the study will be greatly enhanced if Congress requires the various agencies to demonstrate that they have participated in the development of a national plan to achieve the "Oceans 2000" goals, and are adhering to such a plan.

To sum up NOAA's role: NOAA is an essential player if oceanographic research on behalf of this country in the decades ahead is to be successful. Events of the past year have made it clear (at least to me) that a NOAA within the Department of Commerce cannot function effectively. Thus, I believe that the highest priority for both Congress and the Executive should be the creation of an independent NOAA to parallel NSF and NASA.

Sincerely,

G. Ross Heath,
Dean, College of Ocean and Fishery Sciences.

Louisiana Universities Marine Consortium,
Marine Research and Education Center,
Chauvin, LA, October 29, 1984.

Hon. Joel Pritchard,
Subcommittee on Oceanography, Committee on Merchant Marine and Fisheries, U.S. House of Representatives, Longworth House Office Building, Washington, DC.

Dear Mr. Pritchard: I thank you for the opportunity and honor of appearing before the Subcommittee on Oceanography during its recent hearings on marine research. I could not agree more with the observations in your October 12 letter regarding the need for clearer identification of research needs and initiatives and improved coordination between the scientific community and Federal agencies.

To this end, I would like to observe that the scientific community has recently made significant strides toward what should become a clear consensus about what the research priorities should be. I point particularly to the long-range planning of the Advisory Committee on Ocean Science for the National Science Foundation in its report "The Emergence of a Unified Ocean Science", to the Joint Oceanographic

Institutions, Inc. in its report concerning application of satellite technology, and to the ongoing study of the Board on Ocean Science and Policy of the National Research Council. To these efforts, my colleagues and I who appeared on Panel I during the Subcommittee's hearings will shortly submit a combined response to Mrs. Schneider's request for identification of research priorities. There is a need to broaden this planning and consensus building to include the large number of mission-oriented agencies involved in ocean research.

In response to your specific questions of me please consider the following:

1. A part of the problem of translation of basic science information towards resolution of applied problems and the design of monitoring programs is the shortage of translators, that is scientists within the research community and within the agencies who are well versed in both contemporary ocean science and the practical resource management issues. This situation can be improved by encouraging accomplished basic researchers to become involved in the design and conduct of applied research (as contractors, as visiting scholars within the agencies, as postdoctoral fellows and in workshops) and by increasing the basic science exposure of applied research managers. Another contributing factor is the situation that Dr. Schubel so eloquently articulated, wherein estuarine and coastal environments (where most of the practical problems and monitoring programs are based) have been largely neglected in modern process-oriented research. This deficiency should be met by expanded basic science activities (e.g. NSF-supported) in these environments as well as far-sighted applied research programs under sponsorship of mission-oriented agencies (e.g. NOAA, EPA, MMS). Because of the heterogeneity of our coastal environments and the people who study and manage them, development of uniform national policies for the needed research will be difficult. A first step would be development of regional research and monitoring plans developed by cognizant agencies and the scientific community. These can subsequently be refined and made as nationally consistent as reasonable. The Interagency Committee on Ocean Pollution Research Development and Monitoring could potentially be an effective forum for such policy development.

2. I believe that, in general, emphasis in marine pollution research should be placed on estuarine and coastal environments. Thus, the apparent shift in emphasis toward these environments planned by NOAA and EPA is justified. I am concerned that in these new initiatives there may be too much emphasis on strictly descriptive studies, monitoring, and synthesis of existing data and not enough on contemporary process-oriented studies. I believe that a "research void" in continental shelf (OCS) environments can be avoided if the agencies which still focus most of their efforts there (MMS and DOE) wisely use their resources and if shelf environments of special concern (showing signs of incipient degradation) continue to receive attention.

I would be happy to attempt to clarify these responses or my written testimony or answer additional questions.

Sincerely yours,

DONALD F. BOESCH,
Executive Director.

[Committee note.—The U.S. Geological Survey was requested to submit a written statement on its role in marine research. The following text was presented at the Oceans 1984 conference on September 12, 1984 in Washington, DC.]

U.S. GEOLOGICAL SURVEY MARINE GEOLOGY PROGRAM, DALLAS L. PECK, DIRECTOR, U.S. GEOLOGICAL SURVEY

The big news on the marine geology scene undoubtedly is the Exclusive Economic Zone (EEZ) (see chart I. And so it ought to be, because it encompasses and defines a major new frontier. At the same time the EEZ provides, just by its formal existence, a special focus on the mineral and energy potential of the sea floor. The Geological Survey has been in the business of studying and assessing the mineral and energy resources of our national domain for 105 years. That work has included the offshore for more than 40 years, but significant effort in marine geology is little more than 10 years old. Declaration of the EEZ more than trebled the national domain to be studied offshore, including the deep sea floor, with the kinds of mineral potential only discovered or recognized in the last several years.

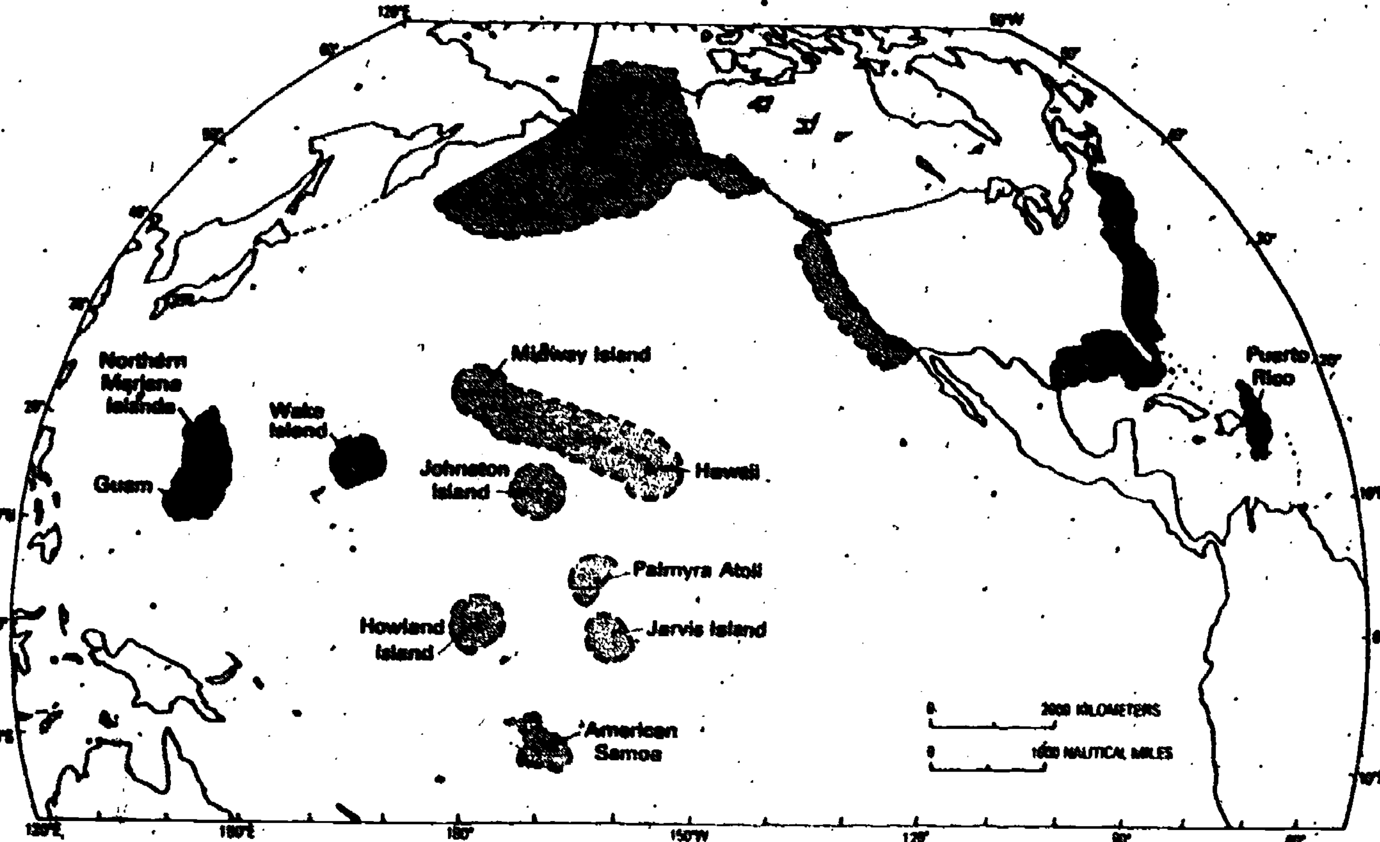

Chart I
United States Exclusive Economic Zone

The Geological Survey is responding to this new, exciting national opportunity with both far-flung exploration voyages and detailed studies of underwater mineral deposits and geologic processes. We are, naturally, concentrating our effort in the United States EEZ, but our geologic studies also serve the Nation in areas as far away as the South Pacific and Antarctica. Geology is a worldwide pursuit, because the linkage of ocean floors and continents through the processes of plate tectonics can be understood only in a context of global knowledge. Most especially, we can gain special insights into the geology of the continents and some major types of ore deposits by studying the processes that formed them millions of years ago on the sea floor. Today's sea floors provide a real-time laboratory in which we can observe those processes that have worked continuously through geologic time.

What are we doing specifically? Last November, at our headquarters in Reston, Virginia, we, along with the Minerals Management Service and the Bureau of Mines, hosted a Department of the Interior symposium on the nonliving resources of the EEZ. At that meeting, we described some of our marine efforts just getting underway and mentioned a number of new ventures that we planned in the near future. Much has happened since then—fiscal year 1984 has been a banner year. This month, our ship, the S.P. Lee, arrives back at Redwood City, California, after a year's voyage from pole to pole along the route shown. The beginning of the trip covered deployment and testing of a new Canadian sea-floor drill on the Juan de Fuca Ridge, and a detailed look at a vent field of polymetallic sulfides. From there, the Lee sailed north to the Bering Sea where we collected multichannel seismic data on frontier basins that are receiving new exploration attention from oil companies. Then south to Hawaii, into the area of Horizon Guyot and the Line Islands, to survey the possibilities of cobalt-rich manganese crusts on the surfaces of the many seamounts in the mid-Pacific region. Many new samples were obtained, including one that showed the unusually high value of 2.5 percent cobalt. Side-scan sonar and bottom photos showed irregular topography and an uneven distribution of the mineral crusts on the sea floor. From this study, it is clear that a lot of effort will be needed before we understand the character, occurrence, and potential of these metal-rich deposits.

The Lee then sailed south to perform 2 months of surveys of Antarctic waters off the coast of Wilkes Land and in the Ross Sea. There multichannel seismic data were collected to link up with data collected by other countries. We already are exchanging data with the geological Survey of the Federal Republic of Germany. These data show the continent-ocean boundary and structured pull-apart basins. They will lead to new, more knowledgeable inferences about the geologic history of the region, as well as the nature of the passive margin of the continent and similar margins elsewhere in the world. Seabed samples were obtained and are being analyzed for age, organic contents, and thermal history. This cruise was a research voyage, the first American venture fully dedicated to antarctic marine geology and geophysics. It was basically for scientific purposes, but it also provided new information of value to the United States and to the world during the present international negotiations for an Antarctic minerals regime. The Geological Survey shares this highly successful and important advance with the National Science Foundation, without whose invaluable logistical support and facilities the cruise could not have been made.

One of the driving forces in the pole-to-pole voyage was a commitment to obtain new information on the regional geology and energy and mineral resource potential of several of the South Pacific island nations. This was the second such cruise sponsored by the Agency for International Development and the governments of Australia and New Zealand. The data are just beginning to be processed and analyzed, but as on the first cruise in the region, they are revealing basin sequences and structures that probably deserve attention for resource exploration. On the return home from the South Pacific, the Lee undertook sampling of seamounts in the Marshall Islands, on behalf of the Department of the Interior. Again, cobalt crusts in the mid-Pacific region appear to be fairly widespread, and commonly contain on the order of 1 percent cobalt. An array of instruments left on Horizon Guyot on the way south was retrieved on the way home. We hope that the recorded observations will help us understand the chemical and sedimentation processes active in forming the metalliferous crusts on the sea floor. The Lee returns home this month after a month of maintenance and repairs in Honolulu by the Hawaii Institute of Geophysics, which operates the vessel for the Geological Survey.

While all this was going on, a broad range of daily research in marine geology produced dozens of scientific products describing the history and character of offshore basins and the sedimentary processes that are active in filling such basins, detailing the tectonics of our Atlantic and Pacific margins, and presenting geotechnical and environmental data of real importance to the future development of OCS resources. We have also been preparing for a series of ALVIN dives to begin in a few days of Juan de Fuca Ridge. This will be major multidiscipline effort to add to our knowledge of polymetallic sulfide occurrence at ocean spreading centers. But, perhaps the most immediately dramatic and visible accomplishment for us have been the GLORIA survey just finished in August. Sidescan sonar images at reconnaissance scale, with about 60-meter resolution, were obtained for the Pacific conterminous EEZ from the Mexican border to the Canadian border, and from the shelf edge outward to 200 nautical miles. These images were acquired digitally and are going to be put through extraordinary cleanup and mosaicking processes to produce an atlas of this 250,000 square miles of sea floor. In a mere 4 months, the British Institute of Oceanographic Sciences covered this frontier area with virtually flawless data. These data already are causing extensive reconsideration of previous interpretations of the tectonics, sea-floor volcanism, spreading center geometry and dynamics, and offshore geohazards. We have discovered meandering river channels hundreds of miles long, put new detail into our thinking about deepsea fan sedimentation, and have found on the order of 100 new undersea volcanoes, some as big as Mount St. Helens, with the same kind of fresh-looking craters and siderlast vent morphology. The new pictures we now have of the junction of the Blanco Fracture with Juan de Fuca Ridge and of the asymmetry from one side of Gorda Ridge to the other, alone are worth the price of admission. To us, these new images rank with the first pictures of the far side of the moon or the surface of Venus in exposing a never-before-seen panorama of planetary geologic processes. In further comparison, however, the value of the GLORIA images seems much more tangible. We have a road map for pinpointing areas for more detailed studies of possible resources and possible candidate sites for ocean dumping. We have new scientific insights into processes of erosion and sedimentation on an active continental margin. Our plans are to produce preliminary atlas maps within a year, and final, cleaned-up versions on rectified latitude-longitude map bases a year after that.

We believe that these images should lead to joint projects with several other Federal agencies that have concerns dealing with the sea floor, and the Geological Survey is working to develop that cooperation. Such cooperation among Federal agencies, between Federal and State Governments, and between Government agencies, academic institutions, and industry are at the heart of the most prominent recommendation that came from attendees at the EEZ symposium last fall: that a national program to explore and develop the EEZ should be organized. From our point of view, that national program is beginning to take shape. The Geological Survey is formally linked by agency agreement with the National Oceanic and Atmospheric Administration, to accomplish modern high-resolution bathymetric surveys of the EEZ and produce up-to-date charts in quick time. In this effort, the National Ocean Service is providing major survey time on two ships, and the Geological Survey is providing some of the funding for onboard data processing and preliminary chart production. Two months of west coast EEZ surveys have already been accomplished to overlay detailed bathymetry on the GLORIA data—a major step in detailed characterization of the sea floor.

We are linked with the Minerals Management Service, providing both road maps of the sea-floor frontier to identify areas of possible future leasing interest, and also detailed studies of identified mineral areas and sea-floor environmental geology. We are working with the Bureau of Mines, providing samples of materials for metallurgical and beneficiation tests, and will be working toward providing site characterization for future development of environmentally safe sea-floor mining methods. Other surveys provide information for the the Corps of Engineers and other agencies in the Department of Defense. With the State Department, we are involved in the South Pacific resource surveys, and we also provide information on the geology and resource potential of United States international boundary areas. Just recently, we have opened a dialogue with the Department of Energy and the Environmental Protection Agency concerning joint interests in sea-floor studies and site characterization. So, on the side of the Federal Government, the list activities and joint ventures is beginning to fill out—it is, of course, a longer list, because I have mentioned only those links that involve the Geological Survey. Our program also reaches outside the Federal establishment. We have cooperative projects with a number of coastal States. From our $19 million of annual funding, we send $4 million to academic institutions, both for ship operations and for scientific studies.

Except for some relatively large purchases of equipment and ship leasing, we are not working with industry the way we will need to do for a truly national program. This last year, we thought a full-scale Government-industry consortium was at hand when the Glomar Challenger was offered as a gift to the Geological Survey. Here was a chance to go after the vitally important third dimension in the OCS, the drill-hole samples to control and enhance interpretation of seismic data and to reveal the nature of the strata and their geologic histories. Our initial thought was that the Geological Survey would manage and maintain the drillship and analyze the drilling results: industry might provide most of the financial muscle to drill about 50 fairly shallow holes per year and put together the understanding of regional geologic settings needed in the national search for energy resources. After a detailed look at prospective budget, however, we had to decide that the program simply was going to displace too many other priorities, and we could not go through with it at this time. However, the need is still just as great and we will continue to explore ways to work with industry to get the job done. We think that this type of venture still offers much promise for Government-industry concert.

Some of that exploration of possible new joint ventures is underway now as the Department of the Interior is considering a possible expansion of EEZ program activities for 1986. The expansion plan is a long way from reality at this time; tentatively, for the Geological Survey, it would include such elements as significantly increased funding for extramural program work in academia, increased deployment of the GLORIA and other side-scan sonar systems in order to survey the entire EEZ, utilization of other newly developing technologies, increased support for bathymetric surveys, and joint ventures with industry in sea-floor drilling and resource studies. An expanded program would focus on gathering new data on the frontier areas of the continental slope and rise and the deep sea floor. But, it also would bring an increased effort to pull together and synthesize existing data for areas already surveyed. While we are waiting for the 1986 budget to be established, we are considering plans to respond to the Senate budget language for 1985. That language, not reconciled with the House as yet, calls for specific studies of the polymetallic sulfide resource potential of the Gorda Ridge. If those studies are indeed funded, the Geological Survey will be entering into cooperative arrangements with oceanographic institutions in the area and with the National Ocean and Atmospheric Administration, the Minerals Management Service, and the Bureau of Mines. We would also be looking for industry involvement in the scientific surveys and in the testing of new survey technology.

Clearly, the oceans and the United States oceanic domain are critical factors in national security and national economic resource development. A national approach and a truly national program are needed. The Geological Survey and our sister agencies in the Federal Government have been defining the roles and the links to begin that approach and to create that national program. We will find the necessary ways to expand that program to include meaningful participation by States, academia, and industry in the scientific and exploration work ahead.

University of New Hampshire,
Durham, NH, October 23, 1984.

Hon. Claudine Schneider,
Longworth House Office Building,
Washington, DC.

Dear Representative Schneider: The September 26, 1984 special hearing of the Subcommittee on Oceanography of the House Committee on Merchant Marine and Fisheries was of significant importance to the U.S. academic ocean science and technology community. We greatly appreciated the opportunity to discuss with you and other members of the subcommittee the status of marine research [illegible] U.S. and to examine the federal research capability. Your interest and insigh[illegible]derstanding of the general situation in our field is appreciated.

Those of us who were on the Academic Panel have discussed your request for further input, and would appreciate the opportunity to develop a unified response which deals with your specific questions. Our response, which we feel will be of use to the whole Subcommittee, will collectively outline our view of the critical academic marine science issues and technology requirements for the next decade. We hope to forward the response to you and the Subcommittee in early November. We have discussed this approach with the subcommittee staff (Candyce Clark and Kathy Minsch), and they agree.

Thank you for your interest in the marine science research community.

Sincerely,

James D. Baker,
President, Joint Oceanographic Institutions Inc.
Robert W. Corell,
Director, Marine & Sea Grant Programs, University of New Hampshire.

JOINT OCEANOGRAPHIC INSTITUTIONS INC.,
Washington, DC, November 13, 1984.

Hon. CLAUDINE SCHNEIDER,
House of Representatives,
Committee on Merchant Marine and Fisheries,
Longworth House Office Building,
Washington, DC.

DEAR MS. SCHNEIDER: On behalf of my colleagues who testified at the recent Hearing on the Status of Marine Research in the United States, I would like to thank you for the opportunity to express our views about issues and opportunities in this important area. At the hearing, you asked us to prepare a statement summarizing priorities for marine research. The enclosed document represents our joint view of critical research initiatives, infrastructural and institutional needs, and the maintenance of critical programs.

In a field as broad as research in the marine environment, there are many competing demands for research support. Scientists and engineers representing disciplines ranging from physics to biology and subjects from global circulation to estuarine mixing all can identify critical and important issues that can be studied with benefit now. In the document, we have tried to weigh these needs with reference to the long range plans that are developing at a number of agencies with significant input from the oceanographic community.

We appreciate your interest in marine research, and we would be pleased to provide further information as required.

Yours sincerely,

D. JAMES BAKER,
President.

OCEAN AND MARINE RESOURCES RESEARCH PRIORITIES AND INITIATIVES

(By D.J. Baker, Joint Oceanographic Institutions Inc., D.F. Boesch, Louisiana Universities Marine Consortium; R.W. Corell, University of New Hampshire; G.R. Heath, University of Washington; D.A. Ross, Woods Hole Oceanographic Institution; J.R. Schubel, State University of New York at Stony Brook)

I. RESEARCH PRIORITIES

Marine research has been characteristically broad and multifaceted, making the setting of a limited number of broadly acceptable priorities difficult. We believe, however, that a limited number of research areas can presently be designated as high priority based either on the opportunity for major scientific advances allowed by new technologies or on societal needs. We suggest that concerted initiatives or strengthened efforts are required in the five subject areas listed below.

1. Global oceanic and climatic processes

New tools and theoretical insights will allow rapid progress in understanding the entire ocean as a system. This will result in important new understanding of the ocean environment and its productivity and world weather and climate. The driving technologies are the satellite missions planned during the next decade and improved supercomputer capabilities. These will allow the collection of huge amounts of data over large scales and the comprehensive analysis of these data. Also related to these approaches are requirements for at-sea sampling and experimentation to provide ground truth and detailed verification. Basic science directions relevent to this theme are largely embodied under the Global Circulation, Climate and Productivity Initiative in the National Science Foundation (NSF) Advisory Committee long range plan "Emergence of a Unified Ocean Science."

These studies will require cooperation of several federal agencies. NASA, NOAA and the Navy will be satellite operators with responsibilities for space technology, weather forecasting, and defense, respectively. The NSF is well poised to lead the advances in scientific understanding which will be required for effective use of these results. As pointed out in the hearing, the basic science track record in open-ocean research is very good and it is reasonable to expect that the academic research community, given adequate support, will make excellent use of these new opportunities. Funding must come primarily from the Federal Government, although it should also be noted that state and private institutions also contribute to the costs of oceanographic research. Because the products of the research will be broadly beneficial to society rather than to the exploitation of a specific resource, the role of the private sector will probably be limited to investments in the technological developments required rather than in primary funding.

The benefits to society of this research are diverse and substantial. Most clearly, the research will allow longer term and more accurate predicitons of weather and understanding of global climate variations. Such insight can help avoid tragic human consequences of natural disasters and plan ways in which the world's burgeoning population can deal with its resource needs in a changing climate. Many other benefits, including technological spin-off, can not be fully imagined at this time.

2. Pathways and fate of materials in the ocean

Coupled with the new understanding of the world ocean circulation discussed above comes the opportunity to make significant advances in understanding, in a fully quantitative way, the biogeochemical pathways and cycles in which the oceans figure so prominently. This involves measuring the fluxes of materials from the atmosphere to the ocean, from the continents to the ocean, and vertically within the ocean. Within the open ocean, the research community is now capable of making comprehensive measurements of vertical flux of both dissolved and particulate materials, including fluxes from the sea floor. In the coastal ocean, it is horizontal flux from the coast and rivers and the flux of materials across the continental shelf which must be better measured. Efforts to accomplish these tasks must involve chemists, physicists, geologists and biologists working in interdisciplinary modes.

The nation's basic science agency, the National Science Foundation, will be expected to lead the way in these fundamental research objectives, although several applied research agencies have some responsibilities or interests in different facets of the problem. The Department of Energy's oceanography program emphasizes fluxes of energy-related materials through the coastal ocean; DOE is also concerned with the fate of carbon dioxide derived from fossil fuels in the atmosphere and oceans. The National Oceanic and Atmospheric Administration has a role in terms of its interests in climate and, together with the Environmental Protection Agency, in ocean pollution. Many of the processes which must be studied bear even on the interests of the Navy (for example, as they relate to ocean acoustics and coastal dynamics) and the Department of the Interior (offshore minerals and energy development).

The benefits of better understanding of fluxes of materials in the ocean include predictions of climatic and sea level changes as a result of the buildup of carbon dioxide and other greenhouse gases. Also, such understanding would lead to safer controls of such potentially harmful substances as persistent synthetic organics, radioactive materials, and excessive biostimulants.

3. Coastal ocean and estuarine processes

Coastal environments provide most of the exploitable marine resources and, at the same time, are the marine environments most susceptible to alteration by man. The record for developing penetrating insight into man's effects on the coastal zone, estuaries and shelf environments has been less than we would wish. Reasons cited at the hearing include the desire for simple or quick answers to complex environmental problems, constraints on scientific innovation, bureaucratic tendencies to overmanage applied research, and the influence of statutes and regulations which direct attention to proximate, "regulatable" problems.

As a consequence there is an insufficient understanding of environmental processes which underlie the pervasive environmental changes which are now being recognized in estuaries and nearshore waters. Such changes include physical alterations of wetlands and shallow water environments, eutrophication and resultant oxygen depletion, and contamination by persistent, synthetic compounds.

In order to develop a level of understanding required for effective management, interdisciplinary and fundamental research on critical processes is needed. Little such research is presently being conducted for estuarine and coastal environments, but the effectiveness of this approach has been demonstrated in open ocean studies. Research should focus on important processes which underlie environmental modifications, including the transport and deposition of sediments, exchange of biologically important materials between sediments and the water column, and controls of biological productivity.

Responsibility for the needed research should be shared between govenmental entities (both Federal and more local) with management responsibilities and the private and governmental bodies which use the coastal environment for waste disposal or other purposes. Governmental coordination, both at the national and regional levels, is required to ensure the effective implementation of research plans. Because of the considerable extent and diversity of coastal environments, in-depth investigations of all U.S. estuaries and coastal waters is impractical. A number of regionally and ecologically representative environments should be selected for such comprehensive investigations.

The benefits of improved understanding of estuarine and coastal ocean processes will be evidenced in enhanced predictive capabilities regarding the capacity of the environments to provide resources in the long term. This would result in wiser and less contentious management of coastal environments and resources.

4. Ocean lithosphere and mineral resources

The exciting discoveries regarding plate tectonics made during the last 15 years will continue to drive exciting new research in the coming decades. Such research will focus on the mechanics of the plates themselves, spreading centers (where ocean floor crust is formed), and the interactions between oceanic and continental crusts. Related to these processes is the desired assessment of the mineral resources of the ocean floor, in particular that under National jurisdiction within the Exclusive Economic Zone (EEZ).

Research will involve a continued program of scientific ocean drilling, application of advanced multi-channel seismic techniques, seismologic networks, and detailed field studies of hydrothermal vents and mineral deposits. Advantage should be taken to maximize the scientific contributions of inventory programs, such as EEZ resource assessments of the U.S. Geological Survey and NOAA.

This research will require Federal support through the NSF (both Divisions of Ocean Sciences and Earth Sciences), USGS, NOAA and the Navy. Private investment in research on economic mineral resources may also contribute, but this will likely be in the far term rather than the near term.

Benefits will accrue generally to society by virtue of improved knowledge of our planet, but will more specifically include better predictions of tectonic activity and identification of mineral resources.

5. Biological productivity and living resources

Opportunities exist for a significant improvement in understanding the bases of biological productivity in the sea and, thereby, the causes for its variations and ability to sustain living resources exploitable by man. In particular, new insight on food chains will allow better understanding of the production of higher consumers (secondary productivity). Also, improved knowledge of biological and environmental factors controlling recruitment in animal stocks will allow explanation and prediction of year-to-year variations in those stocks.

As opposed to other priorities in which quantum advances are expected as a result of new technologies (such as in Global Oceanic Process and Ocean Lithosphere studies), progress in understanding the underpinnings of living resource productivity is likely to be more gradual. Particularly significant to this progress will be the ability to couple physical and biological processes, a goal, for example of the Fisheries Oceanography Cooperative Investigation (FOCI) program of NOAA.

Federal sponsorship of research on this subject should be encouraged principally through NOAA (National Marine Fisheries Service and Sea Grant) and the NSF (the Recruitment Initiative of the NSF long-range plan).

Benefits will relate directly to fishery resource exploitation and management. Furthermore, issues of biological productivity and recruitment are tied to environmental modifications discussed under Coastal Ocean and Estuarine Processes, and consequently, to sound coastal environmental management.

II. INFRASTRUCTURE AND INSTITUTIONAL INITIATIVES

From studies of the coastal zone to deep sea drilling to the sweeping new view of the ocean promised from satellites, oceanographers are looking forward to major new advances in understanding and predicting ocean processes. From this knowledge will come important new practical uses of the ocean and the coastal zone. In order to be ready for these challenges, we need support for both the research initiatives discussed above and the basic infrastructure of the field.

Today in the United States the ocean sciences share two characteristics with the other field and laboratory sciences: pre-eminence in world science, and a deteriorating infrastructure. The former is being challenged by the latter. On the whole, our laboratory equipment is old, we are not up-to-date with computers, our research fleet will need replacement in a few years, and shipboard equipment and handling gear are not adequate for the major new programs that are being planned. Of all the field sciences, oceanography faces perhaps the most severe environmental constraints. The salty and turbulent ocean is harsh and corrosive; instruments and buoys have short lifetimes. Since they operate world-wide, our facilities are also continually subject to changing world economic conditions such as the price of fuel. Three major areas of support can be identified: Research Facilities and Equipment; Capital and Seagoing Facilities; and Educational and Research Personnel.

1. Research facilities and equipment

Many of the instruments available to oceanographers are wornout or obsolete. A program of steady-state replacement of standard instrumentation is required. In addition, we note that both existing seismic data and the new data streams from satellites require that users have ready access to sophisticated imaging systems to process and manipulate results. Distributed access or "nodes" for individual investigators is required, the design to draw on the hardware and software experience of existing facilities.

Needs for seagoing equipment include navigation and data relay equipment for both ships and moored and drifting buoys, new sensors for measuring physical, chemical, and biological properties for periods of at least one year, instrument handling gear, and basic observational instruments used from ships, such as temperature and salinity devices and multichannel seismic instruments. An estimate of costs to provide the necessary equipment is about $13 Million.

2. Capital and seagoing facilities

The oceanographic community currently operates cooperatively three kinds of facilities: large research vessels, the submersible *Alvin*, and the new drilling ship for the Ocean Drilling Program. These will soon be joined by the oceanographic component of the Advanced Vector Computer at NCAR. These are scheduled and overseen by committees representing the entire community. This modus operandi has worked well, but the funding levels have not been adequate.

Other research facilities of importance that need basic support include multichannel seismic facilities, long-term mooring facilities, and an increased capability to take long, high-quality, large diameter cores from the sea floor. These are all existing facilities that need increased support. Estimates of costs required are about $13 Million, excluding ship replacement costs.

As far as new ships are concerned, we support the recommendations of the two groups that are now studying the issues: a UNOLS group and a fleet coordination group under FCCSET. The detailed study of ship replacement needs available there is an important part of the documentation for infrastructure.

As new experimental techniques and scientific demands develop, we anticipate that new facilities will be required and old ones will be retired. Examples of such new facilities include a deep diving submarine that could go to 6 km depth, a dynamically positioned oceanographic ship for physical, chemical, and biological studies, a permanent oceanographic station suitable for multiple and long-term work with heavy deployment capability, and large ecosystem tanks for study of higher trophic levels in marine systems. Advanced computers at individual institutions will also be required.

As federal and state budgets have tightened, capital construction and refurbishing has virtually ceased at our oceanographic centers. Laboratories built twenty to thirty years ago are ill-suited to the analyses of today, with their requirements for ultra-clean areas, large supplies of stable power, air-conditioning and absence of vibration. Many new facilities and instruments are ill-housed. We need a federal commitment to facilitate the raising of matching state and private funds. Costs for two major renewals per year are estimated to be about $20 Million.

3. Educational and research personnel

Three major support groups can be identified as high priority: Marine technicians, equipment operators, and post-doctoral fellows.

Our current levels of staffing and qualification are based on an era when instruments were simpler. As we have moved into the electronic age, the complexity of instruments and the data rates have increased by an order of magnitude. We need an adequate corps of qualified seagoing technicians if we are to continue to collect high quality data.

All fields of oceanography rely, to varying degree, on sophisticated shore instrumentation to attack key scientific questions. The reliable operation of such equipment requires skilled technical personnel and costs about 20% of the purchase price per year. We need on-going support for instrument operators to cover the predictable costs in order to enhance the quality and availability of the suite of major instruments in our institutions. Total costs for new support of research personnel are estimated to be about $10 Million per year.

The global studies of the next decade will require the involvement of bright new oceanographers. Some of these can be found in the existing programs; some will have to be recruited from other science and engineering disciplines. Enhanced post-doctoral support to allow young oceanographers to become established and to provide a period for new recruits to learn the field is the only realistic mechanism to ensure the availability of the researchers who will see the new global studies of such topics as climate, ocean structure, and fisheries through to completion. The costs of an adequate program are estimated to be about $2 Million per year.

III. MAINTAINING PROGRAMS OF CRITICAL IMPORTANCE

The U.S. commitment of excellence in science and technology, and to a scientific and technological base to our industrial and economic development, is founded in a working partnership between government, universities, and industry. The patterns of financial support for these critically important programs has been based largely upon a carefully evolved balance between long term commitments to the ocean sciences by a selected set of leading colleges and universities, and programs and projects of national priority supported by federal agencies.

This balance of financial support must be maintained, with the Federal government providing the foundation of programmatic support for those critical research programs which underpin our evolving understanding of the oceans and coastal margins. The colleges and universities can, with long term programmatic support, maintain the academic programs of education and research and the highly trained faculty and research personnel essential to a productive ocean science and technology program in the U.S.

Several carefully planned and effective federally supported programs form the basis of the critical set of national priorities for maintaining our preeminence in the ocean sciences and technology, essential to maintaining our industrial and economic growth, and to enhancing our national security. These federal programs include basic ocean sciences and technology, marine resources assessment and development, and international ocean science and cooperation.

1. Critical programs in basic ocean sciences and technology

Basic support to the priority programs of the National Science Foundation, the Office of Naval Research (and other R&D programs of the Department of Defense), the National Aeronautics and Space Administration, and related agencies is essential in the following areas:

Biological Oceanography and Marine Biology;
Chemical Oceanography and Marine Chemistry;
Marine Geology and Geophysics;
Physical Oceanography; and
Ocean Engineering and Technology.

Basic support of these core program areas, the priorities for which are established through long range program planning within each agency and by the ocean science community throughout the U.S., is essential to the vitality and health of our fundamental scientific programs in the ocean sciences and related disciplines. These program elements are the foundation upon which the new challenges and exciting opportunities are derived and built. Therefore, it is critical that these underpinning programs be maintained and continued, with annual adjustments to maintain purchasing power. In addition, enhanced funding of selected initiatives will be required in order to take advantage of the exciting opportunities offered by new technological developments, for example, satellite sensing capabilities and supercomputers.

2. Critical programs in marine resources assessment and development

The jurisdictional arrangements evolved in recent international declarations and negotiations has established the 200-mile Exclusive Economic Zone. The extensive marine resources contained therein are the essential natural resources for industrial and economic development of the oceans and coastal margins. The critical research and development programs that are conducted by our academic institutions and supported by NOAA, the USGS (and other R&D programs of the Department of the Interior), the Department of Energy, EPA, and more recently USDA, are essential to a coherent and coordinated program of industrial and economic development of the EEZ and of the coastal margin. Examples of essential research and development programs include:

The National Sea Grant College Programs;
The EEZ Assessment Programs of USGS and NOAA;
The Environmental Assessement Programs of NOAA, DOE and EPA;

The Fisheries and Aquaculture Development and Management Programs of NOAA and USDA; and

The OCS Environmental Studies Program in DOI and related programs in other agencies.

The priority research programs, conducted in university and college laboratories, provide the basic knowledge and understanding essential to the development of our nation's marine resources. Hence, it is critical to maintain current levels of support, with adjustments made annually for new priorities and to maintain the purchasing power of the funds appropriated to these programs, and to provide funds for new initiatives in these areas.

3. International ocean science and cooperation

There are many important ocean science questions to be considered in the next 10-15 years. To study and answer many of them, including their societal impacts, will generally require scientific access to most, if not all, parts of the ocean. This access will be a challenging task as many nations (to date, over 60) accept the general law of the sea conditions, which will lead to over 40 percent of the world's oceans coming under coastal state control for marine scientific research.

This "enclosed" region will include all coastal regions and nearly all continental margins and seas—a critical area of the ocean for research. Access to this area by U.S. ocean scientists will require them to meet certain specific regulations, including the participation of foreign scientists in the research programs. On the whole, the U.S. marine scientific community can probably meet this challenge, however, several actions by the federal government might be especially helpful:

The United States should maintain its present positive position towards the concept that foreign states can control marine scientific research in their waters.

In United States' relationships with foreign countries, we should recognize the potential and possibility of cooperative marine science activities.

The Federal Government should assist United States scientists in the pursuit of foreign research opportunities, possibly through the establishment of an office to encourage and develop cooperative marine scientific endeavors with foreign countries.

It should be emphasized that additional costs will be required to gain access to foreign waters (e.g. planning meetings, duplication and shipping of data and samples, training, etc.). These costs should be included in future appropriations to the federal agencies. The benefits to society, and to our foreign policy, by assisting foreign countries in the marine sciences are difficult to quantify. However, if marine science is valuable to the U.S., then it certainly should be more so to the developing countries as they evaluate and exploit their new marine territories.

[Committee note.—The following two statements were submitted by D.F. Boesch and J.R. Schubel as individual contributions to the combined panel response to Mrs. Schneider's request concerning priorities for marine research.]

SIGNIFICANT CHALLENGES IN OCEAN SCIENCE THROUGH THE NEXT DECADE

(By Donald F. Boesch, Louisiana Universities Marine Consortium)

The following response to the Subcommittee's request for identification of the most significant directions in ocean science is offered from the perspective of a coastal oceanographer who has been involved in many practical issues in marine resource management. However, by virtue of my participation in several National Science Foundation and National Research Council research planning efforts, I feel I have a reasonably good grasp of most issues in contemporary ocean science.

MOST SIGNIFICANT CHALLENGES

For each of the five major areas I have identified I discuss the need for new or enhanced initiatives, suggestions on funding, and benefits to society.

Global ocean processes

New tools and theoretical insights will allow rapid progress in understanding the entire ocean as a system. This will result in important new understanding of the ocean environment and its productivity and world weather and climate. The driving technologies are the planned satellite missions and improved computer capabilities. These will allow the collection of huge amounts of data over large scales and the analysis and "comprehension" of these data. Also related to these approaches are requirements for at-sea sampling and experimentation to provide ground truth and detailed verification. Basic science directions relevant to this theme are largely embodied under the "Global Circulation, Climate and Productivity" Initiative in the NSF Advisory Committee plan "Emergence of a Unified Ocean Science."

These studies will require cooperation of several federal agencies, both civilian and military. The Navy, NASA and NOAA are satellite operators with applied objectives. NSF is well poised to lead the advances in scientific understanding which will be required for effective use of these results. As pointed out in the hearings, the basic science track record in open-ocean research is very good and it is reasonable to expect that the academic research community, given adequate support, will make excellent use of these new opportunities. Funding must come primarily from the Federal government, although it should also be noted that state and private universities also contribute to the costs of oceanographic research. Because the products of the research will be broadly beneficial to society rather than to the exploitation of a specific resource, the role of the private sector will probably be limited to investments in the technological developments required rather than in primary funding.

The benefits to society of this research are diverse and substantial. Most clearly, the research will allow longer term and more accurate predictions of weather and understanding of global climate variations. Such insight can help avoid tragic human consequences of natural disasters and plan ways in which the world's burgeoning population can deal with its resource needs in a potentially changing climate and resource base. Many other benefits, including technological spin-off, can not fully be imagined at this time.

Fate of materials in the ocean

Coupled with the new understanding of the circulation of the world ocean circulation discussed above comes the opportunity to make significant advances in understanding, in a fully quantitative way, the biogeochemical pathways and cycles in which the oceans figure so prominantly. This involves measuring the fluxes of materials from the atmosphere to the ocean, from the continents to the ocean and vertically within the ocean. Within the open ocean, the research community is poised to make comprehensive measurements of vertical flux of both dissolved and particulate materials, including fluxes from the seafloor. In the coastal ocean it is horizontal flux from the coast and rivers and the flux of materials off of the continental shelf which must be better measured. Efforts to accomplish these tasks much involve chemists, physicists, geologists and biologists working in interdisciplinary modes.

The nation's basic science agency, the National Science Foundation, will be expected to lead the way in these fundamental research objectives, although several applied agencies have some responsibilities or interests in different facets of the problem. The Department of Energy's coastal oceanography program emphasizes fluxes of energy-related materials through the coastal ocean and the Department is also concerned with the fate of CO_2 derived from fossil fuels in the atmosphere and oceans. The National Oceanic and atmospheric administration has a role in terms of its interests in climate and, together with the Environmental Protection Administration, its ocean pollution-related responsibilities. Many of the processes which must be studied even bear on the Navy's military interests, for example as they relate to ocean acoustics and the dynamics of coastal environments, and on the offshore mineral development interests of the Department of the Interior.

The benefits of better understanding of fluxes of materials in the ocean include predictions of climatic and sea level changes as a result of the buildup of CO_2 and other greenhouse gases and control of potentially harmful substances (for example, persistent synthetic organic and radioactive materials).

Coastal ocean and estuarine processes

Coastal environments provide most exploitable marine resources and, at the same time, are the most susceptible marine environments to alteration by man. The record for developing penetrating insight into man's effects on the coastal zone, estuaries and shelf environments has been less than stellar. Reasons cited at the hearing include the desire for simple or quick answers to complex environmental problems, constraints on scientific innovation, bureaucratic tendencies to overmanage applied research, and the influence of statues and regulations which direct attention to proximate, "regulatable" problems. This has lead to a situation wherein there is an unsufficient understanding of environmental processes which underlie the pervasive environmental changes which are now being recognized in estuaries and nearshore waters. Such changes include physical alterations of wetland and shallow water environments, eutrophication and resultant oxygen depletion, and contamination by persistent, synthetic compounds.

In order to develop a level of understanding required for effective management, interdisciplinary and fundamental research on critical processes is needed. Little such research is presently being conducted for estuarine and coastal environments, but the effectiveness of this approach has been demonstrated in open ocean studies. Research should focus on important processes which underlie environmental modifications, including the transport and deposition of sediments, exchange of biologically important materials between sediments and the water column, and controls of biological productivity.

Responsibility for the needed research should be shared between governmental entities (both Federal and more local) with management responsibilities and the private and governmental bodies which use the coastal environment for waste disposal or other purposes. Governmental coordination, both at the national and regional levels, is required to ensure the effective implementation of research plans. Because of the considerable extent and diversity of coastal environments, in-depth investigations of all U.S. estuaries and coastal waters is impractical. A number of regionally and ecologically representative environments should be selected for such comprehensive investigations.

The benefits of improved understanding of estuarine and coastal ocean processes will be evidenced in enhanced predictive capabilities regarding the capability of the environments to provide resources in the long term. This would result in wiser and less contentious management of coas[illegible]vironments and resources.

Ocean lithosphere and mineral resources

The exciting discoveries regarding plate tectonics made during the last 15 years will continue to drive exciting new research in the coming decades. Such research will focus on the mechanics of the plates themselves, spreading centers (where ocean floor crust is formed), and the interactions between oceanic and continental crusts. Related to these processes is the desired assessment of the mineral resources of the ocean floor, in particular that under National jurisdiction within the Exclusive Economic Zone.

Research will involve a continued program of scientific drilling, application of advanced multi-channel seismic techniques, seismologic networks, and detailed field stu[illegible] of hydrothermal vents and mineral deposits. Advantage should be taken to [illegible]e the scientific contributions of resource inventory programs, such as EEZ [illegible]

[illegible] research will require Federal support through the NSF (both Divisions of Ocean Sciences and Earth Sciences), USGS, NOAA, and the Navy. Private investment in research on economic mineral resources may also contribute, but this will likely be in the far term.

Benefits will accrue generally to society by virtue of improved knowledge of our planet, but will more specifically include better predictions of tectonic activity and identification of mineral resources.

Biological productivity

Opportunities exist for a significant improvement in understanding of the bases of biological productivity in the sea and, thereby, the causes for its variations and ability to sustain living resources exploitable by man. In particular, new insight on food chains will allow better understanding of the production of higher consumers (secondary production). Also, improved knowledge of biological and environmental factors controlling recruitment in animal stocks will allow explanation and prediction of year-to-year variations in those stocks.

Federal sponsorship of research on this subject should be encouraged principally through the NSF and NOAA (National Marine Fisheries Service and Sea Grant).

Benefits will relate directly to fishery resource exploitation and management. Furthermore, issues of biological productivity and recruitment are tied to environmental modifications discussed above and, consequently, to sound coastal environmental management.

INSTITUTIONAL REQUIREMENTS

The Subcommittee's hearings made clear the fact that for the promises of marine research to be realized institutional arrangements need to be improved. These include 1) improved cooperation and coordination within the Federal government, among all levels of governments and, where appropriate, with the private sector; 2) more effective utilization of the Nation's intellectual resources housed in universities and research institutions; and 8) modernized and enhanced facilities.

Emphasis on short term questions of little inherent scientific interest and rigid policies concerning the selection of performers of research are dissuading the best marine scientists from research on practical problems. Also, the limitations imposed by an aging facility infrastructure in an area of rapid technological development are serious. More substantial programs than currently exist are needed to improve laboratory instrumentation within national centers of excellence in ocean sciences and within regional centers emphasizing coastal studies. In addition, replacement and modernization of research vessels is required in order to meet the challenges of the future.

Estuarine Research Priorities

(By J. R. Schubel, Marine Sciences Research Center)

The most important estuarine studies are comprehensive, multi-year interdisciplinary studies of entire estuarine systems. Many of the most important first-order disciplinary scientific questions in estuaries have been addressed successfully; few of the second order DISCIPLINARY questions have been considered; and almost none of the most important, complex interdisciplinary questions that relate to the interactions of the physical, chemical, biological and geological processes have been studied. It is this level of understanding which is required for effective management. The most important estuarine questions—at least for management—are fundamentally interdisciplinary in character.

The next generation of scientific questions will be enormously more difficult than the first, but it is on the first where most scientists make their reputations. If we are to interest our best scientists in pursuing these questions—and they will require our best if they are to be resolved—the scientists will have to and a source of more stable funding will be required.

The second order questions are complex and are not amenable to facile solutions or to attack by large, short-term (3-5 year) efforts. Basic research on complex estuarine interactions is still inadequate to provide an adequate scientific basis for effective management of estuarine systems including those that relate to pollution management and estuarine rehabilitation.

SOME RESEARCH PRIORITIES

The principal need is for interdisciplinary studies of estuarine systems. But, there needs to be an explicit recognition that disciplinary investigations provide the building blocks necessary for an interdisciplinary framework. Some examples of important research problems are listed below.

(a) Conduct detailed surveys to establish the distributions in time and space of plant and animal populations and to relate their populations to variations in physical, chemical and geological properties and processes.

(b) assess how natural and anthropogenic stresses affect the general structure and function of estuarine ecosystem.

(c) Develop methods to provide Lagrangian flow within estuaries.

(d) Establish the mechanisms responsible for the often rather abrupt transition from stratified to vertically well-mixed and the changes in the internal circulation which accompany these transitions.

(e) Determine the processes that cause estuaries to function as filters for fine-grained sediments and adsorbed contaminants. Relate filtering efficiency to estuarine circulations.

(f) Assess the importance of bioturbation to probilization of nutrients and contaminants.

(g) Assess the effects of episodic storms and floods on the biota, sediment load and chemistry of estuaries.

(h) Assess the relationships between freshwater inflow to estuaries and primary and secondary production, including fisheries landings.

(i) Characterize the sources, routes and rates of sediment transport, the sites and rates of accumulation and the transformations of sediment composition between their points of entry and their final sites of accumulations.

(j) Characterize the processes that control the adsorption and desorption of contaminants.

(k) Characterize the fundamental processes that control the relationships of nutrient levels and estuarine productivity, primary and secondary.

(l) Characterize the pathways that couple primary and secondary production in estuaries.

(m) Establish the relationships between fish production and estuarine habitat quality.

FUNDING

Because of the nature of estuarine systems, because their importance extends well beyond the boundaries of the states which border them, often to the entire Nation, and because many of their most serious problems result from activities throughout their drainage basins, it is appropriate that the Federal government should enter into partnerships with the States to fund research to improve our understanding of estuarine, and to fund development and implementation of management strategies to conserve and, when necessary, to rehabilitate these important natural resources.

The partnerships which have been formed between the Federal government and the states which have been primarily with state environmental management agencies; academic scientists have been largely excluded from these partnerships. If they have been involved at all, it has been through responses to RFP's written by program directors who are not estuarine scientists and which typically are so over-specified as to stifle creativity and innovation and to discourage the best scientist from applying. As a result, much of the science has been marginal in quality and therefore has contributed little to improved management in spite of enormous expenditures. Estuarine science and society have suffered.

Of the existing mechanisms for Federal-state partnerships to fund research in estuaries, the one which I believe has been most effective in stimulating high quality estuarine research is Sea Grant. Sea Grant has been responsive to management, has been successful in attracting good researchers, and has been successful in translating the results of that research into forms usable by environmental managers. If the Sea Grant mechanism were to be used on a larger scale, for multi-year, multi-institutional, interdisciplinary studies some changes in program design and administration would be disirable. It would require extension of intra-state Sea Grant review panels to include more specialists from outside the state, and for many estuaries more active and coordinated cooperations between two or more different Sea Grant programs would be required. The state Sea Grant programs could ensure stable funding and sustained attention to individual estuarine systems if the annual threats to eliminate the National Sea Grant Program were eliminated. The network of Sea Grant programs also provides a good mechanism for inter-estuarine comparisons—something which has been lacking.

The proposed greater emphasis on interdisciplinary programs and NSF also could provide an important mechanism for support of interdisciplinary estuarine studies. I believe it will complement and not replace the role Sea Grant could play in multi-year interdisciplinary studies of individual estuarine systems.

BENEFITS TO SOCIETY

The benefits that would accrue to society from an enlarged and sustained investment in BASIC research in estuaries are enormous. It is only through BASIC research that we will improve our understanding of the natural processes that characterize estuaries. With greater knowledge better—more effective—management can follow through the application of this new knowledge. Without it, we should expect to continue to be ineffective in our efforts to conserve, and when necessary, to rehabilitate estuaries in spite of enormous expenditures. This represents a significant loss of money and a far greater potential loss of enormously valuable coastal resources. On a real basis, our estuaries probably are the most valuable portion of the World Ocean.

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